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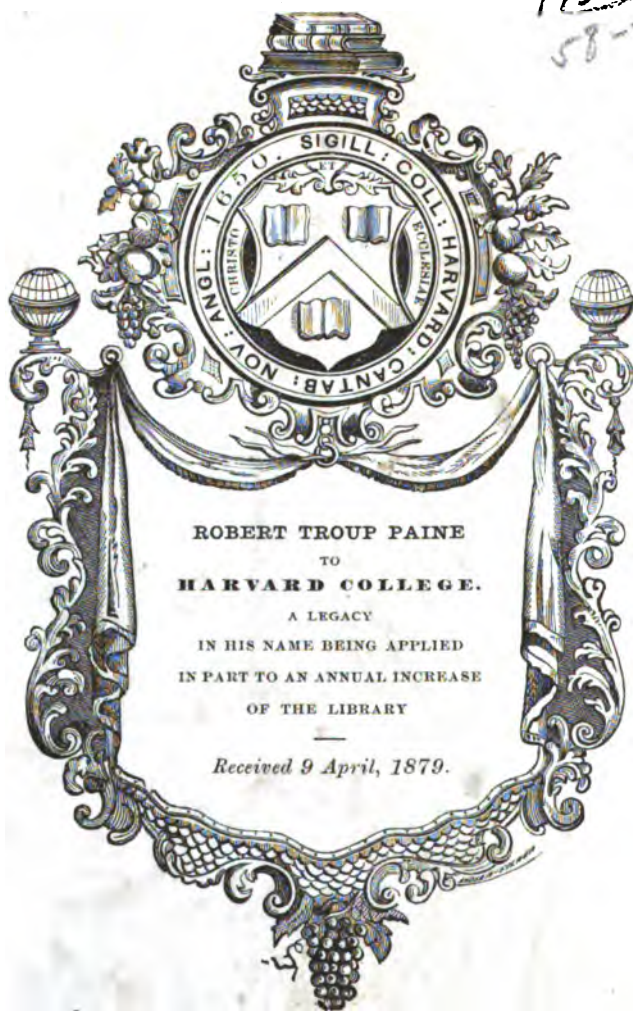
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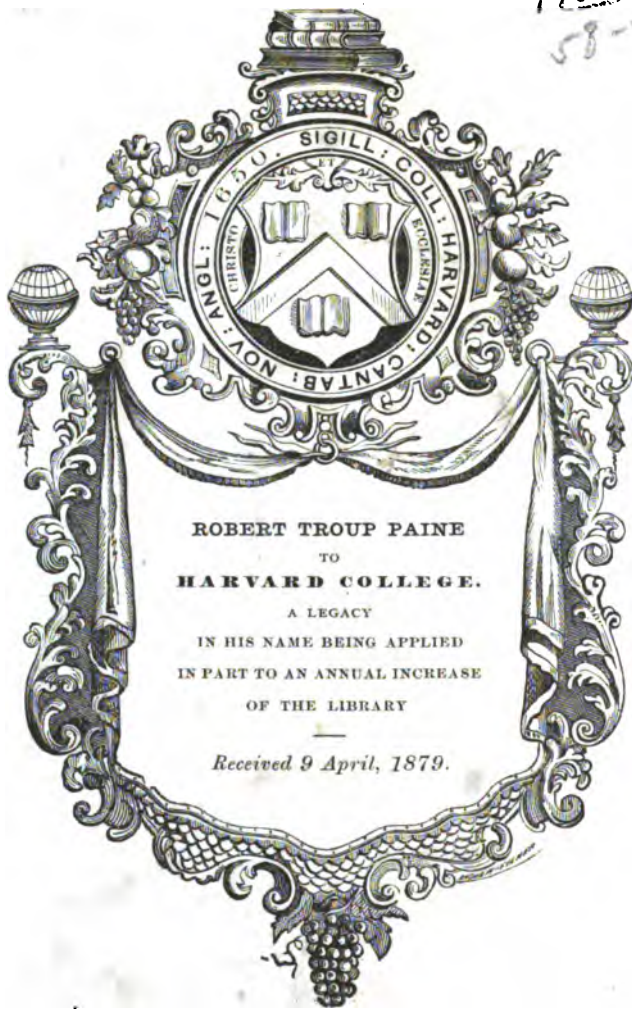
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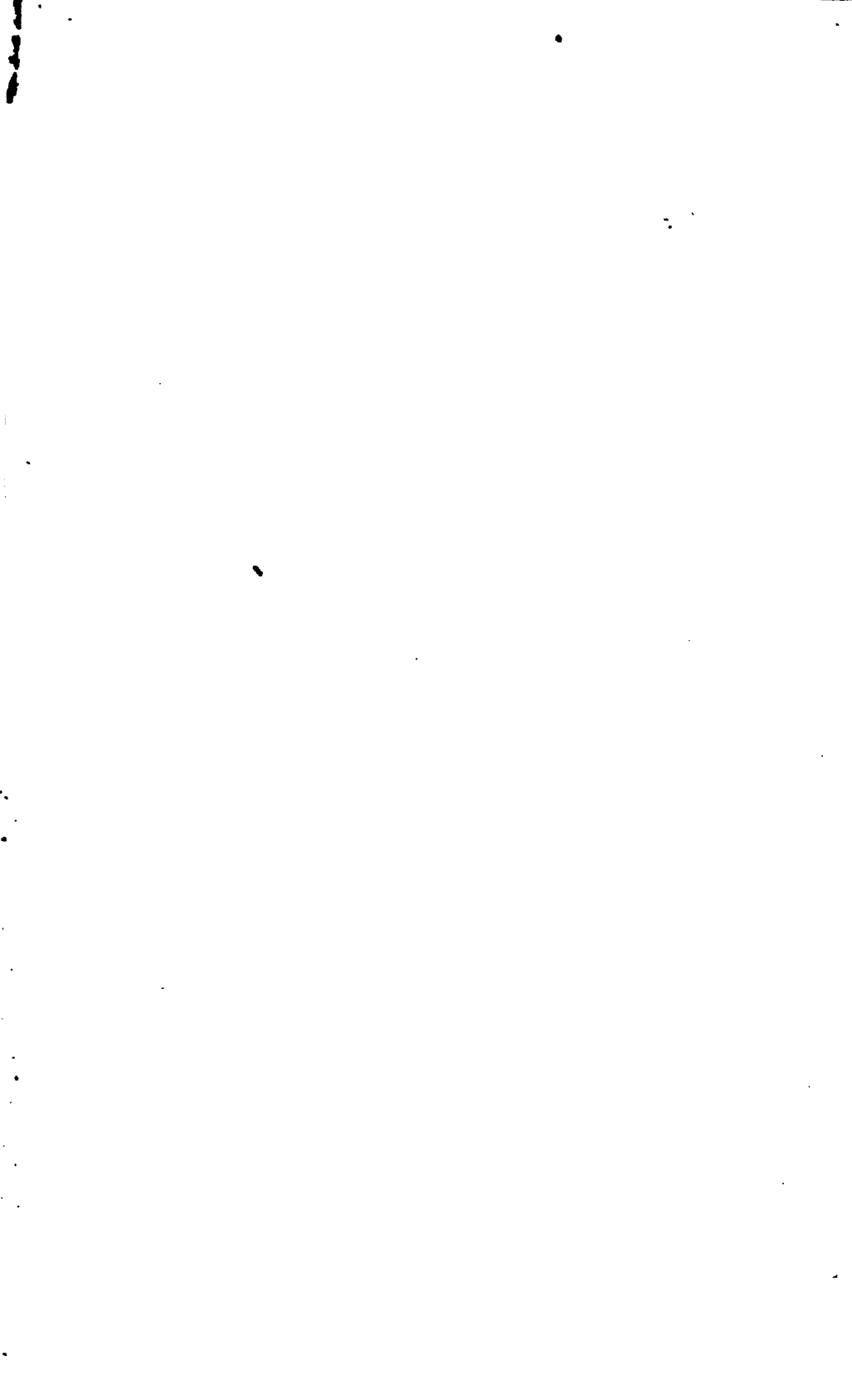
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ELEMENTS
OF
CHEMISTRY,

IN THE
ORDER OF THE LECTURES GIVEN

IN
YALE COLLEGE.

BY BENJAMIN SILLIMAN,
PROFESSOR OF CHEMISTRY, PHARMACY, MINERALOGY AND GEOLOGY.

Robert Troup Paine
IN TWO VOLUMES.
to Harvard College.
VOLUME II.

NEW HAVEN:
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1831.

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1879, April?
S. S. Silliman.

BOUND FEB 26 1910

DISTRICT OF CONNECTICUT, ss.

***** BE IT REMEMBERED, That on the eighteenth day of February, in
: L. S. : the fifty fourth year of the Independence of the United States of Amer-
: ***** : ica, BENJAMIN SILLIMAN, of the said District, hath deposited in this
office the title of a Book, the right whereof he claims as Author, in the
words following, to wit:

"Elements of Chemistry, in the order of the lectures given in Yale College. By
Benjamin Silliman, Professor of Chemistry, Pharmacy, Mineralogy and Geology.
In two volumes."

In conformity to the Act of Congress of the United States, entitled "An Act for
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etching historical and other prints."

CHARLES A. INGERSOLL,

Clerk of the District of Connecticut.

A true copy of Record, examined and sealed by me,

CHARLES A. INGERSOLL,

Clerk of the District of Connecticut.

PREFACE TO THE SECOND VOLUME.



BESIDES the gentlemen named in the preface to the first volume, I have been assisted in the revision of the second, (since the article antimony,) by Mr. George Chilton, of New York, and by Mr. A. A. Hayes, of the Roxbury Laboratory, near Boston; Prof. Tully, of the Medical Institution of Yale College, has also read the proofs, since the commencement of the Vegetable Chemistry, and to him I owe, particularly, the correction of various errors in the botanical and medical references. Most of the gentlemen named in the first volume, have also kindly persevered through a labor, for which my public thanks are but a poor return; should the work prove of any considerable utility, it will have been seriously increased by their valuable suggestions. As my engagements required that the second volume should be finished for the winter classes of the present year, in this Institution, and as my public duties rendered the seasonable fulfilment of my promise difficult, I invited Mr. C. U. Shepard, Assistant in the Chemical Department, to aid me in some of the concluding topics. It will be observed, in the proper place, that the articles on the Analysis of Minerals and Mineral Waters were written by him; I am also indebted to him for the selection of many of the articles in the Addenda, and for collecting and digesting most of the facts on Electro-Magnetism.

The disproportion in size between the volumes, was occasioned by the pressure under which I was laid, to finish the first by mid-winter of last year; it was my intention, otherwise, to have included in the first volume every thing before the Metals, which would have rendered the volumes nearly equal. It was also my wish that the entire work should have been comprised within a smaller compass: I can only say that the subject is vast, and that I have uniformly studied condensation, while it has been my intention, (perhaps imperfectly fulfilled,) to omit no very important facts.

The errata, hitherto observed in this volume, are noted at the end, as well as the additional ones that were deemed of any importance in the first volume, and which the use of that volume during two

seasons, as a class book, has enabled me and my pupils and friends, to discover. I shall feel obliged by a frank communication of any additional errata or omissions, particularly in relation to American science. It is very possible that there are meritorious claims, of which I am ignorant, or that have escaped my recollection; if so it will give me pleasure, should it be ever in my power, to make the proper amends.

In the addenda, some notices will be found of a few additional facts, connected more particularly, with the early part of the work; they have either been discovered, or come to my knowledge, since that part was written, or were overlooked by me at the proper time.

It will be observed by the reader, that the portions of the text in capitals and italics, form in general, such a connected series of principal heads, and leading facts and deductions, that they may, for the greater part, without breaking the sense, be read through in connexion, with the omission of the portions in small roman; and thus a smaller book is comprised within a larger.

* * * * *

I was not aware, until this work was nearly finished, that the *Leçons* of Gay-Lussac were published without his authority; I have quoted them occasionally, and I suppose from the general tenor of his memoirs, and from a comparison with other authorities, that I have not fallen, in consequence, into any error, especially as the *Leçons*, although not authorized by Gay-Lussac, were revised by one of his friends. Whether those of Prof. Laugier, which I have also quoted, were published by his own authority, I am not informed.

Yale College, Feb. 1, 1831.

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ERRATA—VOL. I.

Page 69, (u.) after *alcohol*, insert § (being a reference to a note.)—p. 90, l. 5 fr. top, for 179.2, read 119.2.—p. 124, l. 14 fr. bot. for 1.2340, read 12.340; l. 11 fr. bot. for 3.35, read 1.35.—p. 167, (yy.) l. 4, under *oxygen* in l. 3, read *hydrogen*.—p. 185, l. 11 fr. bot. dele the final *s*.—p. 233, l. 11 of the table, in the column of units, for 9, read 0.—p. 307, l. 17 fr. top, for *proportion*, read *combination*.—p. 319, dele last sentence of 2d paragraph, it being repeated on top of p. 321.—p. 322, 5 (a.) l. 2 of the paragraph, after *has*, read *except the tartaric*. (Turner.)—p. 332, (i.) dele *carbonate of*.—p. 333, l. 19 fr. top, for *ammonia*, read *potassa*.—p. 343, (p.) after *titanium*, read *uranium*.—p. 346, (c.) for *which*, read *whose oxygen*.—p. 353, (3) after *cobalt*, read *titanium, molybdenum*; (5) l. 2 of par. before *hydrogen*, dele *the*.—p. 376, 1(c.) l. 5 of par. for *alkali*, read *acid*; 2(c.) l. 2 of par. for *both acids are*, read *the acid is*.—p. 414, note, l. 16 fr. bot. before *all*, read *at*.—p. 417, l. 14 fr. top, for 11, read 4.—p. 426, l. 10 fr. top, for *phosphoric*, read *phosphorous*.—p. 513, l. 4 fr. top, for *with fluoric acid*, read *with alumina and silica*.

VOL. II.

Page 42, l. 10 fr. bot. for *impossible*, read *possible*; l. 9 fr. bot. for *for*, read *but*.—p. 45, l. 8 fr. bot. after *metal*, read *or an oxide of a metal*; l. 4 fr. bot. after *or*, read *sometimes*.—p. 102, l. 15 fr. top, for 23, read 21.5; l. 22 fr. top, for *specific gravity*, read *quantity of matter*.—p. 164, l. 16 fr. top, for *oxide*, read *cupreous or calcareous phosphate*.—p. 390, l. 15 fr. top, transpose *Mag. grs.* and *Non. mag.*—p. 401, l. 5 fr. bot. for *Acarois resinifera*, read *Xanthorrhæa Hastile*.—p. 455, l. 15 fr. top, (in part of the edition,) for *acid*, read *oxide*.—p. 475, l. 19 fr. top, for *tartaric*, read *citric*.—p. 503, l. 5 fr. bot. after the parenthesis, read *after 2 hours, add sufficient water to cover the mass*.—p. 519, l. 2 of par. (j.) after *gas*, read *except that some acetic acid is formed, when it burns very slowly and with a small flame*.—p. 621, l. 5 fr. bot. for *mastodon*, read *elephant*.—p. 625, (d.) for "metals are positive with respect to acids," read *when acids and metals act chemically on each other, their electricity is the reverse of that produced by contact*.—p. 629, l. 1 fr. top, for *chemical*, read *heating*; l. 9 fr. top, for *metals*, read *powders*.—p. 630, l. 8 fr. bot. for *through*, read *over and at right angles to it*.

The table on p. 48 of the Appendix, should have been placed on p. 33.

CHEMISTRY, &c.

MURIATIC ACID AND CHLORINE.

1. REMARKS.—In unfolding this interesting but rather difficult subject, it will probably contribute to perspicuity to make the student first acquainted with muriatic acid, because it is the parent substance from which chlorine is always obtained. This will also correspond with the chronological order of discovery.*

It will be remembered that, until a recent period, muriatic acid was regarded as an undecomposed body, and it has been already mentioned in this work, that it was in this respect ranked with the boracic and fluoric acids.

Its composition, agreeably to the opinions now generally admitted among chemists, cannot be understood, until we have become acquainted with chlorine; but this will not interfere with the account of the properties of muriatic acid; and its composition can be explained under the head of chlorine.

It is impossible that either of these subjects should be fully understood without a knowledge of the other, and with which ever we begin, we must to a degree anticipate, but we can afterwards return and supply our deficiencies.

2. NAME. From *Muria*, the Latin name of sea salt, from which the acid is usually extracted, the composition being unknown at the time that the nomenclature was formed. It is also called in commerce by the names *marine acid*, and *spirit of salt*.

The French chemists, since the opinion that it is composed of chlorine and hydrogen has been sustained, call it *hydro-chloric acid*, but this name is not very generally in use in the scientific laboratories in English countries, and is scarcely known in those of the arts.

3. HISTORY.

(a.) The acid seems to have been known to Basil Valentine, and was first obtained by Glauber, by the process now in use.

* The historical order is not of course the best scientific one, but it is a happy circumstance when the two coincide.

I am disposed to think that chlorine is not advantageously arranged with oxygen, so as to appear in the early part of the history of particular bodies. (See the plan of the work.) If we regard chiefly its polarity in the galvanic series, and its character as a supporter of combustion, it will indeed be best associated with oxygen; but the facts connected with it are so multiform, and the reasoning is often so complicated, that we need an acquaintance with a large proportion of the most important chemical agents and phenomena, before we can study it intelligently; and its character as a supporter of combustion, and as an electro-negative body is certainly not less intelligible in a later than in an earlier part of the arrangement.

(b.) It was not known as a gas, till Dr. Priestley, in 1772, by heating the liquid acid, obtained and received the gas in glass vessels, filled with mercury.

4. PROCESS.

(a.) *Liberation of Muriatic acid gas.*—Dr. Hare.



A, is a tubulated retort, one third filled with common salt;* the glass funnel, furnished with a stop cock, contains sulphuric acid, one third or one half as much as the salt; on turning the key, the acid falls upon the salt and decomposes it, evolving the gas, which is received in vessels filled with mercury; more acid is allowed to fall as there is occasion, and the heat of a few coals, in the chaffer, C, is eventually applied.

In the above experiment, the glass funnel, although convenient, may be dispensed with, as a tubulated retort answers very well, and even a common one, provided we have a retort funnel.

(b.) *Dr. Priestley's original process is easy,* (3. b.) but as aqueous vapor is distilled over with the gas, the latter is thus in part absorbed.

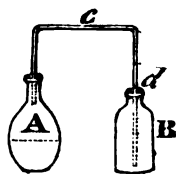
(c.) *Bottles may, without a mercurial apparatus, be filled with this gas, by availing ourselves of its superior sp. gr., by which it easily displaces the common air; thus—*

A, is the flask for the materials,

B, a dry recipient, empty,

c, the tube of communication.

B, being filled with the gas, which is known by its issuing with an abundant cloud, from the mouth of the vessel, by its pungent smell, and by the snowy deposit, when



* Good firm crystals pulverized are better than blown salt, because they are purer.

leather dipped in ammonia, is held at *d*; then the stopper may be reduced, and another bottle slipped on, &c.

6. PROPERTIES.

(a.) *The gas is pungent and suffocating; it is corrosive*, causing hands to smart, as it touches them, especially if moist, and even producing blisters after some time.

(b.) *Causes a white cloud in the air*; this becomes very striking sulphuric acid be poured into muriatic acid, in a tube,* or tall vessel; prismatic hues are often seen in the vapor, especially by transmitted light. The vapor is an acid fog or mist, the gas precipitating the water of the air.

(c.) *Fatal to life*; kills animals confined in it—produces violent irritation and spasms in the glottis, and therefore destroys life in this manner, as well as by suffocation.

(d.) *The gas in jars over mercury is colorless*; Sp. gr. 1.284, air being 1.—Thomson. 1.278, to air as 1.000—Biot and Gay-Lussac. 100 cubic inches weigh 39.18 grs.

(e.) *Extinguishes combustion*; a candle has its flame enlarged, becomes green at the top previous to extinction, and a white vapor, produced by water, floats around the wick. The gas is not itself inflammable.

(f.) *Melts ice almost as quickly as fire would do*; this may be seen by passing a fragment of ice into a jar of the gas, standing over mercury.

(g.) *Electricity partially decomposes this gas, and if in contact only with glass it evolves chlorine and hydrogen*, not exceeding $\frac{1}{3}$ the first volume of the gas; if they exceed that proportion they recombine and form the original gas.†

(h.) *Charcoal, sponge, soft wood and other porous bodies, absorb this gas.*

(i.) *Absorbed with great rapidity by water*; let a drop or two pass into a large jar of gas and the latter will all disappear, becoming liquid muriatic acid.

(j.) *A bottle full of the gas, if opened in water, is almost instantly filled.*

(k.) *If a blue infusion be employed it is beautifully reddened.* A flask or bottle, with a narrow mouth, filled with the gas, as at

* A glass tube, trumpet mouthed, $2\frac{1}{2}$ or 3 feet long, and $\frac{3}{4}$ of an inch wide in the interior diameter, with a glass plate, ground to the mouth, exhibits a very pleasing experiment. Pour into it some strong liquid muriatic acid; then add some strong sulphuric acid; as soon as the common air is expelled, quickly slide on the plate, and invert it with its mouth under water, which, in consequence of the absorption of the gas, will rise with a series of jerks, quite to the top of the tube, and perhaps strike it as with a blow.

† Oxygen and muriatic acid gas, by ignition and electricity, evolve chlorine, owing as is supposed to the union of the hydrogen with the oxygen, and a similar effect is produced by spongy platinum at 250° Fahr.—Henry, I, 270.

(4. c.), p. 2, the finger being used as a valve, if a drop of water is allowed to pass in and agitated, the finger being replaced so as to exclude the atmosphere, the latter, the mouth being immersed, forces in the water when the finger is removed.

(l.) A liquid acid may be prepared, in the small way, by merely passing the gas through water, surrounded by cold water or ice.

(m.) *Water absorbs between 400 and 500 volumes of this gas.*—Sir H. Davy states the absorption at 480 volumes, at 40° Fahr.; Dr. Thomson states, that at 69° Fahr., nearly 418 cubic inches of the gas are absorbed by 1 of water, and that it then occupies the space of 1.34 cubic inches. The solution, when cold, has the density 1.1958; it consists of 40.39 real acid and 59.61 water.

(n.) *Much heat is given out during the condensation of the gas by water; if it is not cooled it will soon boil; it is the latent heat of the gas, thus emerging as it is condensed.*

(O.) CONDENSATION BY PRESSURE AND COLD.—*Effected by Mr. Faraday, (by the apparatus already described,) at 50° Fahr. and under a pressure of 40 atmospheres; the gas was extracted from muriate of ammonia by sulphuric acid. It formed a colorless fluid; refraction less than that of water and like that of condensed carbonic acid.**

MEANS OF OBTAINING LIQUID MURIATIC ACID.—Dr. Hare.

"It may be obtained by saturating water with the gas, in Woulfe's apparatus.—The solution is nearly pure, in all the bottles excepting the first. The liquid acid is also procured by distilling a solution of common salt with diluted sulphuric acid, and condensing the product in a cold receiver. In this case, the aqueous vapor proceeding from the water employed to dilute the acid, rises with the gas and causes its condensation."

"The apparatus described, in the following article, may be employed in procuring muriatic acid, and generally where liquids are to be impregnated with any gas."

Woulfe's apparatus.



* Phil. Trans. 1823.

"This figure is intended to convey an idea of Woulfe's apparatus. The gas evolved in the retort first passes into the globe, where any vapor which may accompany it condenses."

"It then proceeds through the tube to the bottle next to the globe. As the mouth of this tube is below the surface of the liquid, the gas bubbles up through it, so as to promote its own absorption, by the agitation. The excess of gas, beyond the quantity absorbed by the liquid in the first bottle, passes, by means of the connecting tube, to the second bottle, and what is not there absorbed, reaches the third bottle, where the process proceeds, as in the two first. Should any of the gas escape absorption, it may, by the last tube, be conducted under a bell glass in the hydro-pneumatic cistern.

"Supposing the extrication of gas to cease, before the liquid, in the first bottle, is saturated, the absorption continuing, the liquid in the second bottle, might be transferred to the first, in consequence of the rarefaction of the residual gas, rendering it incompetent to resist the atmospheric pressure. In like manner the contents of the third bottle might be transferred to the second. To prevent these inconveniences, there is in each bottle a straight tube fastened air-tight into an intermediate neck, and descending into the liquid. By these means an adequate pressure is opposed to the escape of gas, and yet any diminution of pressure arising from absorption, will be compensated by the ingress of atmospheric air, before the liquid can be drawn over from the next bottle."*

PHARMACEUTICAL PROCESS.

1. *Edinburgh.*—Common salt, sulphuric acid and water, equal weights, the acid mingled with $\frac{1}{3}$ of the water; when cold it is poured on the salt and the gas passed through the remainder of the water; more acid than is necessary is employed to form a bi-sulphate and insure a more perfect decomposition of the salt. The sp. gr. of the acid obtained by this process is 1.170.

2. *London.*—The same, only less acid is employed, in the proportion of 20 parts to 24 of the salt, with $1\frac{1}{2}$ pints of distilled water; $\frac{1}{2}$ a pint of the water is mixed with the acid, to which, when cold, the salt is added; the remainder of the water is placed in the receiver, but less muriatic acid is obtained in this way than with the Edinburgh

* The apparatus represented at (c) p. 2, will answer for the impregnation of water, to a moderate degree, with muriatic acid gas; filling the recipient two thirds full of water and keeping it cold by external application of ice or of cold water often renewed. A useful Woulfe's apparatus may be constructed with wide mouthed bottles, furnished with perforated corks through which the tubes may be introduced; the safety tube may be omitted, without much inconvenience, in all the bottles except one. In all cases where Woulfe's apparatus is used, the first bottle should be devoted to waste, as the product is there always impure. It may be reserved for Galvanic experiments.

proportions, and it seems to be an established fact that a more perfect decomposition is obtained by using more of the decomposing agent than is necessary to form a definite compound.*

PROCESS OF THE ARTS.

1. *Formerly they distilled*, at a red heat, in earthen retorts, *balls of dried clay*,† of the size of a pigeon's egg, 10 parts with 1 of *decrepitated salt*; the decomposition evidently arose from the affinity of the earths of the clay for the alkali of the salt.

2. *In the English and French manufactories, they use not only glass retorts but iron stills furnished with earthen heads, or in France, with a plate of lead.*—In the latter case, by recurved pipes, a connexion is formed with a series of bottles. In England, the earthen head is connected with an earthen receiver containing water.

PROPERTIES OF LIQUID MURIATIC ACID.

(a.) *Purity.*—*The product in the second bottle is always pure*, provided the materials were so; if there is any precipitate with the diluted‡ acid on adding muriate of baryta, the acid must be again distilled from a little common salt, or cautiously decanted from the precipitated sulphate of baryta, the receiver and the first bottle generally contain sulphuric acid, as does the acid of commerce.

(b.) *Sp. gr. by the usual process* 1.170; cannot be easily obtained higher than 1.196§; that of the pharmacopœias is generally about 1.160, of which one hundred grains are saturated by 124 of crystallized carbonate of soda; that of commerce is generally about 1.156; if it is more concentrated than this, it is so fuming that it is difficult to keep it, and it is very injurious to metallic articles in the laboratory.

* Murray, Vol. I, p. 692.

† Or, powder of salt 1 part with 2 of the earth; a paste is formed of this, and balls made of it, as large as a hazel nut, are dried in the sun and then distilled in stone or coated glass retorts.—*Gray's Op. Chem.* p. 427.

‡ If the acid is strong it precipitates the muriate of baryta undecomposed, by seizing the water of the solution; it may easily be known whether the precipitate is muriate or sulphate of baryta, as the former will be readily dissolved by a copious addition of water; the sulphate would remain undissolved.

§ Dr. Thomson says (*First Prin.* Vol. I. p. 86,) that in winter he has obtained it as high as 1.212, and Dr. Henry (*Vol. I. p. 278.*) states that by using ice with Woulfe's bottles, it may be made to approach 1.500.

Table from Dr. Thomson, shewing the sp. gr. of acid of different degrees of strength.

Proportion of acid.	Proportions of water.	Acid in 100.	Sp. gr.
1 - - - 6	- - -	40.659 - -	1.2030
1 - - - 7	- - -	37.000 - -	1.1790
1 - - - 8	- - -	33.945 - -	1.1620
1 - - - 9	- - -	31.346 - -	1.1490
1 - - - 10	- - -	29.134 - -	1.1390
1 - - - 11	- - -	27.206 - -	1.1285
1 - - - 12	- - -	25.517 - -	1.1197
1 - - - 13	- - -	24.026 - -	1.1127
1 - - - 14	- - -	22.700 - -	1.1060
1 - - - 15	- - -	21.512 - -	1.1008
1 - - - 16	- - -	20.442 - -	1.0960
1 - - - 17	- - -	19.474 - -	1.0902
1 - - - 18	- - -	18.590 - -	1.0860
1 - - - 19	- - -	17.790 - -	1.0820
1 - - - 20	- - -	17.051 - -	1.0780

(c.) *The acid of commerce is always colored yellow*; sometimes from muriate of iron arising from impurities in the materials, or from the vessels employed; with a Woulfe's apparatus this color does not reach the second bottle unless it is caused by nitre, which is sometimes present in common salt,* and then generates nitro-muriatic acid, and of course chlorine. For some reason the acid is rarely quite colorless.

(d.) When a bottle containing *strong muriatic acid* is opened, it emits fumes exactly like those produced by *muriatic acid gas* in the air, and they arise from the same cause; they are pungent and suffocating.

(e.) *The gas is extricated from the aqueous solution, by heat*, as already stated, and may be collected over mercury.

(f.) *Liquid muriatic acid is not decomposed by the contact of charcoal, essential oils or other combustible bodies.*

(g.) *Taste, intensely acid—not so corrosive as the nitric or even the sulphuric acid*; reddens the blue test colors.

(h.) *Combines with water in every proportion; the temperature rises, but not as much as with the sulphuric acid*, and when the mix-

* The smell of chlorine is often perceived in the muriatic acid of commerce: it will then dissolve gold. I have known so much chlorine obtained in the common process for muriatic acid gas, as to be evident by its color and smell, and by the corrosion of the quicksilver over which it was obtained. In that case however, I had reason to suppose that the nitre had been accidentally mixed with the common salt. Previous calcination would decompose the nitre, and also any vegetable extractive matter which may be present, and which sometimes colors the acid.

- ture is cold, it does not occupy the united volume of both fluids ; there is therefore an increase of specific gravity, and a diminution of capacity for heat, according to the received theory on that subject.

(i.) *Boiling point, 110° Fahr. or a little higher ; it varies, however, with the strength of the acid.* The higher the gravity, or what is the same thing, the more gas is combined, the lower is the boiling point. Acid of the sp. gr. 1.203, boils at about 107°. But there is according to Dalton, a maximum boiling point, which is 232°, and then the fluid contains real acid, 20.442, and water, 79.558 ; if the acid be either weaker or stronger than this, the boiling point is lower.* This appears to be the most intimate combination of the acid with water.

(j.) *This acid, like others, combines with the alkalies, earths, and metallic oxides,* and their carbonates, and forms salts which will be described in their place.

(k.) *It attacks those metals that are easily oxidized ;* with zinc and iron, for example, it gives out hydrogen gas, proceeding however, as is supposed, from the decomposition of the water, and not of the acid.

Remark.—The sulphuric, the nitric, and the muriatic, are the three cardinal acids of chemistry and the arts. We could effect very little in practical chemistry without them. Of the three, the sulphuric is the most useful, because, besides its own numerous and important applications, it is the principal instrument in making the other two ; where there is a manufactory of sulphuric acid, the nitric and muriatic acids are easily made. It has been already stated, that to obtain the sulphuric acid, we burn sulphur in leaden chambers ; nitric acid is separated by the sulphuric from nitre ; and the muriatic, by the same agent, from common salt. In general, the sulphuric acid has a stronger attraction for bases than either of the others named above.

Distinctive characters.—The sulphuric acid is very heavy ; it is inodorous, and if exposed to the air, rapidly increases in weight ; it never evaporates, but acquires weight, at common temperatures ; it gradually chars animal and vegetable bodies, and corrodes them violently if heated with them.

Nitric and nitrous and muriatic acid, are fuming, odorous, and suffocating, and the nitric, if strong, acts violently on combustibles, and sets many of them on fire ; poured on hot charcoal, it causes it to burn with brilliant scintillations. Muriatic acid dropped on the burn-

* Thomson, First Prin. Vol. I, p. 87.

ing coals extinguished the fire as water would do ; it is lighter than either of the others.

USES.

1. *In medicine.*—A valuable article of the *materia medica*, and employed generally as the other mineral acids are.

The muriatic acid is commonly considered to be *tonic*, in a moderate degree, and it is likewise *deobstruent*, that is, it acts on the secreting and absorbent system, changing its condition and action. It is used in those cases of dyspepsia that are attended with morbid secretions,—also in hepatic derangements, cutaneous diseases, low fevers attended with morbid secretions in the stomach and intestines, scrofula, etc. Externally it is *rubefacient* and *vesicatory* and also *caustic*.*

2. *It is also used as a disinfecting agent.*†—It is common in the fever wards of hospitals and in private houses, to liberate the muriatic acid from common salt, by means of sulphuric acid—an earthen vessel and a few coals being all the apparatus that is wanted. It corrects the bad odor and counteracts the contagion.‡

3. *In the arts,* to form muriate of tin for the dyers, &c.

Remark.—I shall so far deviate from the course hitherto adopted, as to omit the account of the muriates until we have become acquainted with chlorine—since the views now entertained of the constitution of those bodies cannot be understood without a knowledge of chlorine.

* Prof. Tully. Y. C.

† At Dijon, in France, there is a cathedral, which in 1773, was, from the corpses under the floor, so much infected with putrid miasmata, that it had been deserted after a number of unsuccessful attempts to remove them, and purify the air, by explosions, aromatics, &c. Application being made to Prof. Morveau for a remedy, he took a glass vessel, supported by one of cast iron, and placed it on a few live coals in the middle of the church. He then put into it six pounds of common salt, and two pounds of sulphuric acid, and hastily withdrew, closing the doors after him. The gas soon filled the vast space, and could be perceived even at the doors. At the end of 12 hours, the church was thrown open and ventilated, when every disagreeable odor was found to be completely removed. Some have supposed that chlorine was, in this case, evolved by manganese added to the salt and acid ; but chlorine was not known till the next year, 1774. I have examined Morveau's original memoir in the *Jour. de Physique*, for 1773, p. 436, and find that the facts are correctly stated as above.

It is important that no valuable articles of metallic furniture or ornaments should be within reach of the gas.

Some workmen, within my knowledge, having let loose this gas for the purpose of disinfecting a room where there had been fever, observed that the clock was soon stopped. They had heard that galvanism is evolved by acids, acting on metals, and conceived they had made the discovery that galvanism would arrest mechanical movements. A gentleman who was present, anxious to bring the supposed discovery to a trial, opened his costly gold watch and held it immediately over the vessel from which the gas was rising. It stopped very promptly, and he shewed it to me a few days after, completely ruined—its fine wheels being covered with a green crust, and its steel springs with iron rust.

‡ Dr. Hope stated in a public lecture, in Edinburgh, at which I was present, that this practice was begun by Dr. Johnstone, at Worcester in England, before it was used by Morveau.

SIMPLE SUPPORTER OF COMBUSTION.

CHLORINE.

I. HISTORY AND IMPORTANCE.—*Discovered in 1774,* by Mr. Scheele, of Sweden*, during his experiments on the black oxide of manganese; he was trying the effects of acids upon this substance, and on adding muriatic acid to it, chlorine gas made its appearance. After oxygen, the discovery of no single body has proved so important to chemistry as that of chlorine. Both in theory and practice, these two bodies touch almost every part of the science, and their application to the arts is extensive and important.

II. NAME.

(a.) *Called by its discoverer, dephlogisticated marine acid*, according to the views of a phlogistic principle which then prevailed.†

(b.) *By the French, denominated oxygenated or oxygenized muriatic acid*; for a reason that will presently appear. Dr. Pearson contracted the word *oxygenized* to *oxy*—.

(c.) *In 1809, Gay-Lussac and Thénard suggested, that oxy-muriatic acid might be a simple body, and Sir H. Davy, being engaged in the same inquiry, soon after proposed the name CHLORINE*, from the Greek *χλωρος*, alluding to the color of the gas, and this name, preferable on every account to the former ones, is now universally adopted.

III. PROCESS.

(a.) *Common muriatic acid 8 oz. with 3 or 4 oz. black oxide of manganese*, in a tubulated glass retort with a gentle heat, applied when the gas begins to relent, *gives 160 cubic inches of gas*, which may be received over warm water.

(b.) Or, (Faraday's Manipulation,) 8 parts common salt, 3 black oxide of manganese, 6 sulphuric acid, and 4 times its bulk of water. The acid and water should be mixed, and allowed to cool before hand; otherwise the materials are very prone to boil up and choke the tube or the neck of the retort.‡

* It is remarkable that the discovery of the two most important chemical agents, namely, oxygen and chlorine, should have been made in the same year—oxygen by Dr. Priestley, in England, and chlorine by Mr. Scheele, in Sweden. Dr. Turner places the latter discovery in 1770, but Mr. Scheele's Essay, is dated 1774.

† From an attentive study of the essays of Mr. Scheele, and particularly of that on manganese, I was many years ago impressed with the truth of the ideas recently expressed by Mr. John Murray, jr. in the 6th edition of his father's Elements, (Vol. I, p. 669.) and find that in a MS. on manganese, written in 1807, I have uniformly translated Scheele's "extrication of phlogiston," by "combination of oxygen," and his "combination of phlogiston," by "extrication of oxygen," so that according to his statement of the facts, dephlogisticated was oxygenated muriatic acid, the very term afterwards adopted by the French. The essays of Mr. Scheele are highly instructive and interesting, and no one of them is more so, than that on manganese, date as above, 1774.

‡ Authors differ a little in the proportions; but as the manganese is cheap, it is better to use a little more than is needed, than not to supply oxygen enough. More or

(c.) 1 oz. *muriatic acid*, with 3 or 4 *drachms chlorate of potassa* ; but the gas thus obtained is a mixture of chlorine and its oxides.

(d.) *Muriatic acid with red lead*—red oxide of mercury and other oxides, which yield their oxygen easily, will produce chlorine.

Dry bottles placed under a good flue, may be filled with chlorine gas by a tube passing to the bottom and conveying the gas from the vessel in which it is generated ; it will lift out the atmosphere and occupy its place, and the intensity of the color will enable us to judge when the bottle is filled, which may then be stopped and kept for use.

The theory of these experiments is omitted until we are farther advanced in the history of chlorine, except that we may now say that the production of the chlorine is, in all these cases, (except c,) owing to the action of oxygen upon muriatic acid.

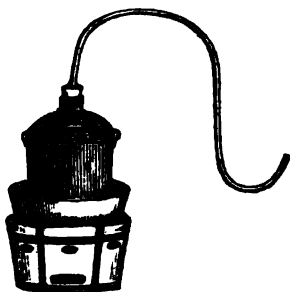
IV. PROPERTIES.

(a.) *Greenish yellow color*, which is permanent in the gas, but ceases when it enters into combination ; it is a gas inherently colored, and its oxides have a still deeper hue.*

(b.) *Smell intolerably suffocating and oppressive.*

(c.) *Dangerous in the lungs* ; occasioning the most painful and distressing stricture and spasm of the glottis, even when largely diluted with air. It thickens the mucus, irritating the membrane, and the

less water should be mixed with the sulphuric acid, as we wish a quicker or slower operation. It is better, however, when we use sulphuric acid and salt with the manganese, to employ a weaker acid quite cold, and to apply heat from the beginning. A pot, as in the figure annexed, of the capacity of two gallons, made of sheet lead, with a strong trumpet-shaped mouth, and a lead tube thrust through a cork smeared with wax, forms a very good apparatus where considerable quantities of gas are wanted. It may be placed in hot water, contained in a tin plate pan, standing on an earthen furnace or a chafing dish, and thus we have a good water bath, which insures a regulated and moderate heat, in imitation of the process of the arts. When the acid is added, it should be done under a good flue, and the lead pot allowed to stand there till the gas comes pure and freely, when it may be quickly moved to the water bath previously arranged, at the destined place. The materials should not fill more than one fourth of the vessel. The gas should be received in vessels filled with warm water, (about blood heat,) and if it is to be preserved for any length of time, it should be conveyed into glass bottles with good ground stoppers, smeared with tallow, inverted with their mouths under water, and placed in a dark and temperate situation.



* We might be disposed to attribute the color to the density of these gases ; sufficient matter being, as may be imagined, concentrated at any given point to project light to the eye, were not fluo-silicic acid gas, which is still heavier, quite invisible when dry. The nitrous acids appear to be gases, and they are deeply colored. Chrome gives colored gases, and perhaps there may be others.

oppression and stricture sometimes continue a good while. The greatest care should be taken to avoid respiring it.

(d.) *Sp. gr.* 2.500, air being 1.000; this is Dr. Thomson's conclusion;* and taking the sp. gr. of hydrogen at 0.0694, chlorine is just 36 times heavier, for $0.0694 \times 36 = 2.500$, so nearly that the difference may be neglected. 100 cubic inches of this gas at 60° F. and 30 inches pressure, weigh 76.25 grains. Gay-Lussac and Davy agree very nearly with this statement.

(e.) *Water, recently boiled, absorbs, at 50° , 2 volumes of chlorine and gives it up again when long heated.*—This solution is most conveniently made in Woulfe's bottles, in which, if kept cold by ice, it will absorb still more of the gas. For common purposes, it is done with sufficient facility and effect, by filling a wide mouthed bottle with cold water, expelling half of it by chlorine gas, placing the hand over the mouth or introducing a tight glass stopper, and agitating the gas and water together; the latter will assume the color of the gas; then open the bottle under water, some of which will be forced in by the atmospheric pressure to supply the absorption; now add more gas and agitate as before, and so on, until the water is saturated; in this way, it will absorb half its volume or more. It should be kept in a dark place and with the mouth of the bottle down.

(f.) *The solution has the smell of chlorine; it is astringent and not sour, if free from muriatic acid*, in which case it will not precipitate nitrate of mercury, and it can be distilled without expelling all the chlorine from the water.

(g.) *It does not redden, but destroys vegetable colors*; and hence its use in bleaching, which will be mentioned more particularly farther on.

(h.) *Aqueous solution of chlorine, exposed to the sun's rays, evolves oxygen gas*; according to the present views, this proceeds from the decomposition of water. (See p. 16.) In the dark, the oxygen is not evolved.

(i.) *If galvanized, the chlorine and the oxygen of the water go to the positive, and the hydrogen of the water to the negative pole.*

(j.) *Dry chlorine is permanently æriform* in every common fluctuation of temperature and pressure. It remained fluid, with Sir H. Davy, at -40° , having been previously dried by fused muriate of lime.

(k.) *Humid chlorine, such as is obtained over water, is condensed into a crystalline solid at $+40^{\circ}$; it is called hydrate of chlorine, and contains chlorine, 1 proportion, 36, and water, 10 proportions, $90 = 126$, or per cent. chlorine 27.7 + water, 72.3 = 100.†—Faraday.*

* First Principles, Vol. I, p. 79.

† Or, rather 71.44, and 28.56.

(l.) *It is obtained by simply surrounding a jar of common chlorine gas with ice or snow*; better by adding a little water to the gas and keeping it for a few days at about 32° in a dark place, when it will shoot into delicate prismatic crystals.* As the water grows warmer, the solid hydrate turns again into chlorine gas.

(m.) *Chlorine by pressure applied in an exhausted glass tube by a syringe, is condensed into a yellow fluid*, and a similar result is obtained by heating to 100° F. in a bent tube hermetically sealed, the solid hydrate previously dried between folds of blotting paper.

In Mr. Faraday's experiments, the water of the hydrate was tinged of a faint yellow; there was a fluid below of a dense yellow, and an atmosphere of the same color in the tube. The bright yellow fluid was supposed to be the liquefied chlorine, and as the tube cooled, the yellow atmosphere became condensed into a yellow fluid, resting on the pale one. The condensed chlorine under a pressure of nearly 4 atmospheres, is limpid and fluid; has probably a sp. gr. of about 1.33; is very volatile, and rushes explosively into chlorine gas when relieved from pressure, by breaking the tube. (For other particulars, see Faraday in Phil. Trans. for 1823.)

(n.) *Chlorine, by sudden compression, gives out light as well as heat*, and no other simple gas, except oxygen, becomes luminous by compression.

(o.) *Dr. Hare first observed that chlorine gas produces a sensation of warmth in the skin*, but without affecting the thermometer or warming other objects. Nitrous acid vapor, as already stated, is at the moment when the gases combine, sensibly warm, and it then imparts heat to other substances.

(p.) *Neither light, heat, nor electricity, affects dry chlorine gas or alters it at all*; facts which go strongly to support its elementary character, and are not easily explained upon the other view.

* * * * *

Remarks.—Chlorine is a supporter of combustion. It combines directly with every combustible, except carbon;† and the same is true of oxygen, with the exception of silicon.† *These two, are therefore the only agents that deserve to be called simple supporters of combustion*; the action of phosphorus, sulphur, iodine, &c., with the emergence of heat and light, is so different in the results, and the cases are so peculiar, that it is better not to confound them with at least all common cases of combustion, which are confined to the agency of oxygen, and this is the only mode that mankind are generally acquainted with, and from which all our notions of this process are derived.

* These crystals raise the temperature of alcohol 8° or 10° ; evolving ether and muriatic acid, and a triple compound of chlorine, carbon, and hydrogen is formed.

† These exceptions are only apparent as these combinations can be made indirectly.

V. ACTION OF HYDROGEN AND PRODUCTION OF MURIATIC ACID.

WHEN CHLORINE AND HYDROGEN GAS ARE MINGLED IN EQUAL VOLUMES, THEY DISAPPEAR, AND MURIATIC ACID EQUAL TO THEIR UNITED VOLUME IS THE RESULT; this is effected in several ways.

1. *By electricity, they explode in the detonating tube, with the emission of heat and light; and are converted into muriatic acid.*

2. *By flame or an ignited body; by the radiation from charcoal,* ignited in the galvanic current and by spongy platinum.*

3. *By the diffuse light of day, the mixed gases will in twelve or fourteen hours disappear; if mixed in a bottle with a tight stopper, and if the bottle be opened, at the end of that time, under water, it will be instantly filled, and the fluid will prove to be very dilute muriatic acid.*

If the same mixture had been kept in a perfectly dark place, there would have been no action and the gases would have remained unchanged.

If the mixed gases, especially in a volume of several quarts, be exposed to the direct solar rays, they detonate with great violence; and a cloud of muriatic acid gas appears, while (if the volumes were equal,) neither hydrogen nor chlorine remains.†

VI. THEORY OF THE PHENOMENON.

1. *Nothing can appear more obvious, than that the two gases combine and form muriatic acid.* It is apparently as satisfactory a conclusion, as that water is formed by the union of oxygen and hydrogen.

* Phil. Trans. 1820, Mr. Brande. While this light was equally effectual as the sun's rays, no other terrestrial light had any effect, nor had the lunar rays. A mixture of these gases in a Florence oil flask once exploded in my hands in a very snowy day, and with no apparent cause but their own reaction. See Am. Jour. Vol. III. p. 342.

† Having several times repeated this remarkable experiment, (first made, I believe, by Gay-Lussac and Thénard,) I will mention, that it appears to me to succeed better in green glass than in white; that I have usually filled a green flask of from two to four quarts capacity in the pneumatic cistern, covering it first with a thick brown towel, and pouring in the hydrogen last. With gloves on the hands, and goggles on the eyes, the flask is then tightly and firmly corked, while its mouth is still under water. An additional towel may then be placed over the flask, and both towels may be tied together at one corner to a long string. The vessel may now be carried into the sun's rays, when there is no cloud, and the operator keeping the string in his hand, may, when at the distance of at least fifty feet, pull the towels off with a sudden jerk, and retire still farther. Sometimes the explosion is instantaneous, and at other times, we may see an undulation of misty vapor, evidently that of muriatic acid, rapidly revolving in the flask, and immediately after comes the explosion, which appears to be more violent than that of oxygen and hydrogen. I have sometimes placed the flask in a box, and pulled the lid open with a string. I have not found it answer well to leave the mouth of the flask open and standing in water. In that case, I have more than once known the combination to take place, rather rapidly indeed, but without explosion.

This fact is the basis of the present theory of chlorine, and it is inferred from it and from other facts, still to be mentioned, that chlorine is an elementary body.

2. *The combining power of chlorine is expressed by 36,** and that of hydrogen being 1, it follows that muriatic acid gas must be represented by 37, and if 50 cubic inches of hydrogen weigh 1.059 grs. and 50 cubic inches of chlorine 38.125, 100 cubic inches of muriatic acid should weigh 39.184, as already stated.

VII. FORMER OPINION OF THE NATURE OF CHLORINE.

This is sufficiently expressed by the name which was given to this agent in the French nomenclature: oxygenized muriatic acid was supposed to be composed of muriatic acid, an undecomposed body, and oxygen. Hence the explanation of the processes for obtaining it was, that the black oxide† of manganese, or some other body imparted oxygen to the muriatic acid.

The present view is, that muriatic acid being a compound of chlorine and hydrogen, the oxygen operates to detach the hydrogen from the muriatic acid, and thus to liberate the chlorine: according to the old opinion chlorine is formed by the union of its principles; according to the new it is simply let loose; it is in the latter case an educt, in the former one a product. The new view has in most respects, the advantage of the old, but there are facts which seem to me to be imperfectly explained by either. It will still be interesting and instructive as a part of the history of the science, to give the explanations of the principal facts upon both theories, although in accordance with the decision of the chemical world, I adopt the new; with an impression however, that some fact or facts not yet discovered, will hereafter evince to us that we have not fully understood the subject.

Remarks.—Now that we are acquainted, with the composition of muriatic acid, as at present admitted, we may explain such things as were not elucidated in giving its history.

The evolution of chlorine and hydrogen from muriatic acid by electricity and galvanism, is supposed to arise from a decomposition; the acid being resolved into its elements; the former opinion would have been, that the decomposition of water gave oxygen to the muriatic acid to form oxy-muriatic, and left hydrogen at liberty, and that thus the two gases were found in mixture.

A mixture of oxygen and muriatic acid gas being electrified together, or transmitted through an ignited porcelain tube, the oxygen

* This is higher than the equivalent of any simple substance except the metals and iodine.

† The oxide of manganese is found to lose oxygen and to pass from the state of per to that of prot-oxide.

takes the hydrogen, forms water, and liberates the chlorine ;* or upon the old view, the oxygen unites with the muriatic acid, and forms oxy-muriatic acid.

The present view, as to the union of chlorine and hydrogen to form muriatic acid, has been already given ; the other concludes that hydrogen and the oxygen of oxy-muriatic unite to form water, which combines with the liberated muriatic acid, to whose existence in the form of gas, it was supposed to be essential.

The explosion of the mixed chlorine and hydrogen gases, by the solar ray, is explained upon the supposition that chlorine is a peculiar and energetic supporter of combustion, thus made instantaneously effectual.

This fact was not known, at the time when the old theory was in vogue, but the explanation would plainly have been, that the oxygen of the oxy-muriatic acid aided by solar light, caused the hydrogen to explode. This is very improbable, since no such effect is produced by a mixture of pure oxygen with hydrogen in proper proportions, and it is scarcely credible that oxy-muriatic acid, containing, as was believed, but a sixth part of oxygen, should produce effects in combustion that oxygen alone cannot produce.† This is a strong point in the new theory.

The evolution of oxygen gas in the solar rays, from the aqueous solution of chlorine, is now explained by the decomposition of water, which gives its hydrogen to chlorine, to form muriatic acid, while the oxygen is liberated. By the old theory, the oxygen would be derived from the oxy-muriatic acid, while muriatic acid would remain.

VIII. OTHER FACTS ILLUSTRATING THE PROPERTIES OF CHLORINE.

CASES OF COMBUSTION, OR COMBINATION.

1. *Common combustibles.*

(a.) *A burning candle introduced into chlorine, continues to burn, but with a diminished flame and a red light ; and much black smoke or carbon is evolved in a dense cloud mixed with muriatic acid gas ; the acid is, on the new view, supposed to be formed by the hydrogen of the candle, uniting with the chlorine ; or on the other view, to remain from the decomposition of the oxy-muriatic acid.*

(b.) *Chlorine spontaneously inflames some combustibles.*—A rag containing spirits of turpentine, fastened to a wire thrust through a cork and lowered into a tubulated jar or a bottle of chlorine,

* Phil. Trans. 1824.—Still chlorine is supposed to displace oxygen from its combinations.

† It may be said, perhaps, that oxy-muriatic acid is a peculiar substance possessing properties that do not belong to its constituents, but the products of its combination are, by the theory, supposed to be such as do belong to them, and the agency exerted to be therefore that of the elements, and not of the compound.

presently bursts into flame, but without explosion, and fills the vessel with carbon. The theory is the same as in (m.)

2 *Phosphorus*, introduced into dry chlorine gas, *emits, spontaneously, brilliant jets of fire, and burns with a pale white light*, but with less splendor than in oxygen gas.

In the annexed figure (of Dr. Hare,) provision is made by a flaccid bladder fastened at the tubulure, for the expansion of the chlorine gas by the heat; in this way the fumes are kept from escaping into the room. A bent tube passing under an air jar, may be substituted for the bladder.



Products of the combustion of phosphorus.

Chloride of phosphorus.—This is the name now given to the product of the combustion of phosphorus in dry chlorine.

The term is in analogy with oxide.

There are two chlorides; the second containing twice as much chlorine as the first, and called, therefore, bi- or per-chloride.

The per-chloride is formed in the above experiment, the chlorine being in the proportion of at least 12 cubic inches of gas, to 1 grain of phosphorus.

(a.) *Properties.*—A snow white solid—volatile at a heat less than 212° —fuses under pressure, and crystallizes in transparent prisms. Its peculiar properties are seen only when it is dry; it acts violently on water, which, by decomposition, gives oxygen to form phosphoric acid, and hydrogen to form muriatic acid.

It flames by a lighted taper; with oxygen, in an ignited glass or porcelain tube, it forms phosphoric acid and liberates chlorine. Dry litmus paper is reddened by its vapor.

It combines with ammonia, with much heat, forming a compound insoluble in water, not decomposed by acids or alkalies, and resembling an earth.—*Davy.*

(b.) *Composition.*—Phosphorus 1 grain, combines with 6 of chlorine, and as there appear to be two equivalents of chlorine, =72, and 1 of phosphorus 12, the equivalent of the compound is 84.

(c.) *Proto-Chloride of Phosphorus.*—Formed by heating the per-chloride with one seventh of phosphorus, or better, by passing the va-

por of phosphorus over corrosive sublimate, in a heated glass or porcelain tube; calomel is produced, and the chloride or proto-chloride of phosphorus is formed. The corrosive sublimate being regarded as a per-chloride of mercury, is supposed to give up one proportion of chlorine to the phosphorus, and thus becomes the chloride or proto-chloride of mercury.

(d.) *Proto-Chloride of phosphorus is a limpid fluid; sp. gr. 1.45; its vapor burns in the flame of a candle; it does not redden dry litmus paper, but its vapor, which it emits into the air, acquires oxygen to form phosphorous acid,* and hydrogen to form muriatic acid with the chlorine. Water is decomposed by it with heat, and gives the same result. In chlorine it forms the per-chloride. It acts upon ammonia, and produces the same compound as the other chloride, while phosphorus is evolved.—Davy.*

Its constitution is, phosphorus 1 prop. 12 + chlorine 1, 36 = 48.

3. *Sulphur.*—*Sulphur absorbs chlorine gas, both with and without the aid of heat; a stream of chlorine gas may, for this purpose, be passed over flowers of sulphur, or the latter may be heated in a retort filled with chlorine gas. Ten grains of sulphur absorb 30 cubic inches of the gas, and a chloride of sulphur is formed.*

(a.) *† It is a red fluid, (if seen by reflected, but yellowish green if seen by transmitted light,) pungent, offensive and irritating to the eyes, like peat smoke, with an odor like that of sea weed, but much stronger; it is distilled at a temperature below 200°. Sp. gr. 1.6. Dry litmus paper is not reddened by it, but if water is added, sulphur is deposited, and muriatic, sulphuric and sulphurous acids are obtained; the necessary elements being furnished by the water. Alcohol and ether have similar effects, and it decomposes ammonia.*

(b.) *It is composed of chlorine 1 prop. 36, and 1 of sulphur, 16, so that its equivalent number is 52.*

It does not unite with bases to form salts.

It exhibits no acid properties until water is added to it. It would seem therefore that chlorine forms peculiar compounds with both phosphorus and sulphur, and that the facts are not so well explained upon the old theory as the new.

4. *Carburetted Hydrogen.*—*The light carburetted gas and chlorine do not act if dry, nor when moist if kept in the dark; but when moist, action comes on in common day light, and especially in the sun's direct rays.*

(a.) *In the light, with 4 vols. chlorine, and 1 carburetted hydrogen, filling a closely stopped bottle, in a few hours there remains 1 vol.*

* Which is said to be obtained best by the intervention of this chloride.

† Discovered by Dr. Thomson, Nich. Jour. 8vo. Vol. VI.

carbonic acid, and the rest, being muriatic acid, is suddenly absorbed on opening the vessel under water.

(b.) *Direct solar rays sometimes cause large quantities of the mixed gases to detonate, an effect produced also by electricity and by flame.*

(c.) *With 3 vols. chlorine, and 1 carburetted hydrogen, the residue is carbonic oxide.** The decomposition of water affords oxygen to form carbonic acid, in the first case, (a.) and carbonic oxide in the second, (c.) while its hydrogen, with that of the inflammable gas, forms muriatic acid. By the old theory, the oxygen would be derived from the chlorine, and the muriatic acid would be the residuum.

(d.) *Olefiant gas, or bi-carburetted hydrogen gas.*—Between this gas and chlorine there is a decided action, independently of light.

Dr. Henry points out the following method of separating the light carburetted hydrogen from the heavy, or olefiant, founded on the fact that the latter is not acted on by chlorine without the presence of light.

(e.) *Chlorine and olefiant gases, in equal volumes, saturate each other.*—To a given volume of chlorine, add a little greater volume of the gas in question, and eventually a little excess of chlorine, carefully shading the vessel by an opaque cover, and at the end of about ten minutes, cautiously raising it for inspection; if there is no diminution, there is no olefiant gas present, and half the diminution, when it occurs, is attributable to that gas. After removing the excess of chlorine, by washing with solution of potassa, the remainder is pure light carburetted hydrogen.†

(f.) *Chloric ether, or hydro-carburet of chlorine.*—This elegant substance was first supposed to be an oil,‡ and thence the gas which generates it was called olefiant gas.

(g.) *Preparation.*—In the pneumatic cistern, introduce into a large bell glass, 2 or 3 quarts of chlorine gas, and then, rapidly, rather more than an equal volume of olefiant gas,§ instantly sliding beneath the water a large flat dish or plate full of water; absorption will immediately begin, with warmth, and a cloud of vapor; water must be poured in to supply the absorption, till it ceases; the oily substance will soon appear as a film upon the water, and will form itself into drops, and fall to the bottom. The water may be cautiously pour-

* Turner.—Henry.

† The method used would remove olefiant and carbonic acid gases, but not nitrogen.

‡ Discovered in 1796, by the associated Dutch Chemists, at Haarlem.—Ann. de Chim. Vol. XXI, p. 48. The discoverers suggest, in their original memoir, that this fluid is rather an ether than an oil.

§ It is important that the olefiant gas should be added last, that by its comparative levity it may mingle with the chlorine; by reversing the order, I once met with a spontaneous explosion of the two gases, for the reason and particulars of which, see Am. Jour. Vol. X, p. 365.

ed off, and the oily fluid, with the remaining water, decanted into a funnel, stopped by the finger, and thence conveyed by another funnel into a vial: it may be freed from chlorine by agitating it with solution of caustic potassa, and purified still further by distillation from dry muriate of lime.

(h.) *Properties.*—*Resembles an oil, color yellowish, but white when purified; sinks in water, in distinct globules, which readily run together.* Sp. gr. at 45° , 1.22. By much agitation is diffused in the water, and partially dissolved, imparting to the water its own peculiar taste, which is *sweetish, penetrating, aromatic, and agreeable.* Taken internally, it is *stimulating and reviving.* For this purpose it is dissolved in alcohol,* and the alcohol can then be diluted to any desired degree. Its medicinal powers have not been ascertained, but from its constitution and properties, it is highly probable that it would be an active diffusive stimulant.

(i.) *Boiling point* 152° Fahr.; unaltered by distillation; decomposed by ignition in porcelain tubes; products, charcoal, light carburetted hydrogen, and muriatic acid. Decomposed by sulphuric acid and chlorine evolved.

(j.) *Composition and proportions.*—As the two gases combine in equal volumes, their ratios are expressed by their sp. gr.

Chlorine	2.5	or 1 proportion,	36	72 per cent.
Olefiant gas,	.9722	"	14	28
3.4722 Equivalent No. 50			100	

Density of the vapor, 3.4434, corresponding very nearly with the weight of the constituent gases, united volume for volume, two in one.

At 46° its vapor supports 24.66 inches of mercury.

Chloric ether appears to be a compound of chlorine and olefiant gas, or of chlorine, carbon and hydrogen, and this view is correct, whether chlorine be regarded as simple or not.

5. *Carbon.*—*The direct union of carbon and chlorine appears to be impossible by any means hitherto attempted.* Charcoal cannot be made to burn in this gas even when its ignition is sustained, for an unlimited time, by the most powerful galvanic action, which is very extraordinary, as chlorine, in other cases sustains combustion so powerfully.

(a.) *Chlorides of carbon* have nevertheless been formed by the ingenuity of Mr. Faraday, who availed himself of the ternary compound, consisting of chlorine, hydrogen, and carbon, which has been already described under the name of chloric ether.†

* Which happens, instantly, by agitation in a vial.

† For the details of very complicated processes, recourse must be had to Mr. Faraday's paper, Phil. Trans, 1821, p. 47, and again to the remarks of Mr. R. Phillips, p. 392. It would not be proper to introduce into a concise elementary work, such long details of substances, as yet comparatively unimportant.

(b.) *Perchloride of carbon.*

(c.) *Process.*—This consists substantially, in admitting chlorine gas to chloric ether, with the action of the sun's light; muriatic acid is generated, and chlorine is introduced in its place, and so on for three successive trials, when the hydrogen of the chloric ether is found to be removed, and a compound of chlorine and carbon appears in the form of crystals in a dry state, and muriatic acid fills the vessels.

(d.) *A similar result is obtained by exposing to the sun's light a mixture of 8 or 9 volumes of chlorine with 1 of olefiant gas.* The substance is purified by careful washing with water and sublimation, and by the action of alcohol which dissolves it: potassa precipitates it, removing the muriatic acid, and the muriate and alkali being washed away by water, the substance is dried between folds of blotting paper, and by the action of sulphuric acid in the exhausted receiver.

(e.) *Properties.*—*A white pulverulent substance; if pure, subliming without residuum, and giving no precipitate from its ethereal solution by nitrate of silver.*

(f.) *Nearly tasteless; odor aromatic like camphor; sp. gr. about 2, friable, resembles white sugar in consistency; a non conductor of electricity, crystallizes in plates by sublimation, or from solution in alcohol or ether; the primitive form a right rhombic prism. It evaporates spontaneously, and seeks the light like camphor; melts at 320° Fah. boils at 360°; condenses from rapid sublimation in an incrustation, at first so limpid that, but for its highly refractive powers, (1.57—higher than that of flint glass,) it would scarcely be perceived; as it cools it splits and becomes opaque. Its vapor in a red hot tube is decomposed, evolves chlorine, and leaves fluid chloride of carbon; if oxygen gas be present, carbonic acid and oxide, &c. are also evolved. Hydrogen produces muriatic acid. It burns red in the flame of a spirit lamp, and brilliantly in oxygen gas; it is scarcely soluble in water, but easily in alcohol and ether, and especially in the latter when hot: it crystallizes on cooling, and beautifully upon a glass plate even when cold.*

(g.) *Soluble in volatile and fixed oils; the solutions, when heated, become charred, and evolve muriatic acid gas. Unaltered by acids and alkalies; peroxides of metals, such as those of mercury and copper produce by ignition with its vapor, chlorides, and carbonic acid; and protoxides, give chlorides and carbonic oxide.*

(h.) *Chlorine exerts no action.*—Sulphur and iodine unite with it by fusion, and the latter flies off by an increased heat. Phosphorus also combines with it at a low temperature; at a higher degree it burns brilliantly in the vapor, and liberates charcoal, which is sometimes suspended in beautiful films in the tube where the flame passed.

(i.) Most of the metals decompose it with heat, form chlorides and deposit charcoal. *Potassium burns brilliantly in the vapor. Ignited*

lime, baryta, and strontia, with vapor of the chloride, produce a vivid combustion, and the chlorine and oxygen change places.

(j.) *Composition and Proportions*.—Mr. Faraday, from the experiments detailed in his memoir, concludes that this chloride consists of

Chlorine, 3 proportions,	$36 \times 3 = 108$
Carbon, 2	$6 \times 2 = 12$

120 which is

therefore its equivalent number.

(k.) *Proto-Chloride*.—*Process*.—By distillation of the per-chloride through ignited fragments of rock crystal, in a glass tube bent in the colder part into a zigzag form; this part is separated and sealed and the fluid distilled back and forward till it is freed from the solid per-chloride, which is known by the fact that the proto-chloride evaporates without residuum from a glass plate.

(l.) *Properties*.—One proportion of chlorine, aided by the heat, escapes and leaves a limpid fluid; sp. gr. 1.55; is an electric; has a refractive power of 1.48, nearly that of camphor; in the flame of a spirit lamp burns with a bright yellow light and evolves smoke and muriatic acid. Fluid at 0 F., vaporised under water at 160° or 170°, insoluble in water; soluble in alcohol and ether and gives a greenish flame; soluble in oils fixed and volatile; not affected by alkalies, acids or solution of silver; by ignition with oxygen evolves chlorine and carbonic oxide or acid, with hydrogen gives muriatic acid, chlorine and charcoal.

(m.) *Composition and proportions*.—By Mr. Faraday's analysis, by ignition with peroxide of copper, it appears to consist of chlorine 1 proportion, 36 + carbon 1, 6 = 42, which is therefore its equivalent number.

(n.) *Sub-Chloride*.—Discovered by M. Jölin, of Åbo, in Finland,* and brought from Sweden to England.

In the distillation of crude nitre, in iron retorts, with calcined sulphate of iron, from the waters of the mine of Fahlun, the receivers being connected by glass tubes in the manner of Woulfe's bottles, the first tube was found to contain sulphur and the second fine, white, feathery crystals, which, on examination, proved to be a chloride of carbon.

By ebullition with liquid potassa, washing in water, drying and subliming, it was freed from sulphur and obtained in white plumose crystals.

* *Annals of Philosophy*, Vol. I, p. 216, and *Phil. Trans.* 1821, p. 392.

(c.) *Properties*.—White adhesive fibres; insoluble in water, in which it sinks; tasteless; smells like spermaceti; acids and alkalies do not affect it; soluble in hot spirits of turpentine and in boiling alcohol; sp. gr. .816; crystallizes on cooling; burns greenish blue in the flame of a lamp; sublimes slowly at about 250° without melting, and melts, boils and sublimes, between 350° and 400° , condensing in long needles. Potassium burns vividly in its vapor, evolving carbon and muriatic acid.

(p.) *Composition and proportions*.—According to the analysis of Messrs. Faraday and R. Phillips, this chloride* consists of chlorine 1 proportion, 36 + carbon 2, 12=48, which is therefore its equivalent number.

Remarks.—Although there is no direct union between chlorine and carbon, it is now obvious that there is an affinity, which is made active by the peculiar state in which carbon exists in olefiant gas and in chloric ether. A part of the chlorine removes the hydrogen to form muriatic acid and another part unites with the carbon to form the chlorides that have been described.

Their properties, especially those of the per-chloride, are however not such as might have been expected. In other cases where chlorine is much concentrated, as in the chlorate of potassa and in the oxides of chlorine, there is an easy decomposition, and great energy of action upon combustible bodies; but the reverse of both these facts is true in this case.

This series of compounds is happily illustrative of the law of definite proportions.

The per-chloride contains, proportions of chlorine 8 of carbon 2

proto-chloride,	1	1
sub-chloride,	1	2

6. *Carbonic oxide and chlorine*—producing *chloro-carbonic acid* or *phosgene gas*.

(a.) *Discovered by Dr. John Davy in 1812*,† who found that the sun's rays, or even diffuse light, will cause the combination of chlorine and carbonic oxide, although some eminent chemists had failed to produce this result.

(b.) *Process*.—Equal volumes of the two gases, previously dried by fused muriate of lime, are introduced into a dry exhausted glass globe, which is then exposed to the sun's direct rays for 15 minutes;

* No theory is given of the origin of this chloride whose appearance is rendered very singular by the circumstances. Probably there was marine salt in the nitre, which with the nitric acid, would generate the chlorine, and carbon must have been present in the materials in some form, if not in that of olefiant gas.

In passing the vapor of this substance over ignited lime, there was vivid ignition and charcoal evolved, and this was one mode of analysing the substance.

† Phil. Trans. 1812, p. 144.

the color of the chlorine will be destroyed, and the two volumes of gas will be condensed into one.*

(c.) *Name*.—As there is no mode known of producing this gas, except by the agency of light, it was called phosgene, from $\phi\omega\varsigma$, light, and $\gamma\eta\omicron\gamma\mu\alpha\iota$, to produce.

(d.) *Properties*.—As the two equal volumes of gas occupy only one volume, the *sp. gr.* must of course be the sum of the specific gravities of the constituents; chlorine 2.5 + carbonic oxide 0.9722 = 3.4722, and 100 cubic inches must weigh 105.90 grains; for 100 cubic inches of chlorine weigh 76.25 grains and 100 of carbonic oxide 29.65.

(e.) As it has acid properties, it is now called *chloro-carbonic acid*. *Odor, intolerably pungent and suffocating*, irritating the eyes and causing a copious and painful flow of tears. *Reddens litmus paper*; water generates with it muriatic acid and carbonic acid, supplying hydrogen to the chlorine and oxygen to the carbonic oxide, or, as the old theory would have explained it, oxy-muriatic acid, giving oxygen to the carbonic oxide and muriatic acid being left.

(f.) *It condenses 4 volumes of ammonia and forms a white inodorous salt*, with a pungent saline taste; producing no effect on the test colors; evolving carbonic and muriatic acid gases by the agency of the stronger acids, but subliming unaltered, in muriatic, carbonic and sulphurous acid gases, and dissolving in the acetic acid without effervescence.

(g.) *It is decomposed by tin and by several of the metals, which form with it chlorides*, and carbonic oxide is evolved, precisely equal in volume to the compound gas. Chlorine and carbonic oxide, passed through an ignited earthen tube, do not unite.

It is worthy of remark that this acid gas has a simple base, namely, carbon, and two acidifying principles, chlorine and oxygen, a rare, perhaps a solitary combination.

(h.) *Composition*.—Chlorine 1 proportion, 36 + carbonic oxide 1, 14 = 50, which is its equivalent number.

7. *Nitrogen*.—*Chloride of nitrogen*.—*Discovered by M. Dulong,† in Paris, in 1811.*

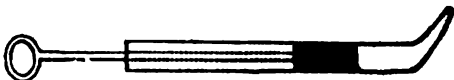
(a.) *Process*.—*No direct combination of chlorine and nitrogen is known; it is formed by the action of chlorine upon an ammoniacal salt*, and my experience accords with the general statement, that *nitrate of ammonia is the best*. *Dissolve*, in a perfectly clean glass vessel,

* The dried gases being mixed, in a tube, over mercury; if the sun's rays fall upon it, the color of the chlorine will vanish in a minute and the absorption by the mercury will be finished in ten minutes.

† Who is said to have lost an eye and a finger by its explosion, and Sir H. Davy had nearly lost an eye in the same way.

1 part of this salt in 12 of water,* and place over it a tall jar of chlorine gas. In a short time there will be an absorption and a film of an oily looking substance, greatly resembling the chloric ether, will appear, and collecting into drops will fall to the bottom. Or, muriate of ammonia 1 ounce dissolved in 12 or 16 ounces of hot water. When it is cooled to 90° , place in it a wide mouthed glass bottle full of chlorine, standing in a vessel of lead; in about 20 or 30 minutes the globules of the detonating substance will be collected.†—Turner.

(b.) No more of this substance should be prepared at once than is to be used in the experiment; the instrument represented below has been recommended, and I find it very convenient, for managing the fluid without danger. It is made of a clean glass tube of uniform bore, bent and drawn to a small orifice, and a wire, around which is wrapped tow to act as a piston, enables one to draw up a single globule at a time, and to transfer it to another vessel or apply it to use.



(c.) Properties.—The most powerful detonating compound known; it explodes with a brilliant light at the heat of 212° , but not with that of 200° ; it may be distilled in close vessels, at or below, 160° , but it remains fluid at -16° Fahr. and at the degree of cold generated by snow and muriate of lime.

(d.) A non-conductor of electricity; sp. gr. 1.65, color yellow, like that of olive oil; transparent, perfectly fluid, smell nauseous, strongly resembling that of the phosgene gas; in a vacuum, it is vaporized, and the vapor is absorbed by water.

(e.) Its disposition to explode is its most remarkable property.—This is effected by heat, and by contact with combustibles. I find that it is done with safety, by allowing a very minute globule, not larger than a pin's head, to fall from the height of 2 feet, towards a warm shovel; it explodes in the air, before it reaches the shovel.

(f.) When combustibles are employed to explode it, they should not be contained in glass or earthen vessels, but in those of metal.—We generally put a few bits of phosphorus into a small bell metal mortar, and cautiously drop the fluid, when there is a series of sharp crackling reports.

* This is the proportion recommended by Mr. Brande; I have generally employed a solution considerably stronger.

† Sir H. Davy attempted to form it by passing chlorine gas through Woulfe's bottles, containing ammoniacal solutions, but the apparatus was soon blown to pieces. I have prepared this compound several times and have never met with an explosion, but too much caution cannot be observed in conducting the process.

(g.) *It is not exploded equally by all combustibles. Olive oil, whether simple, camphorated, or sulphuretted, oil of turpentine, phosphorus, and naphtha, are very certain ; but alcohol and ether, are said to prevent its explosion. Charcoal has no effect upon it. The most complete account of its properties is to be found in an elaborate memoir, by Messrs. Porrett, Wilson and Kirk.* These gentlemen exposed the chloride of nitrogen to the contact of 125 substances, and among them, 101 failed to produce explosion. Among those things that produced that effect, (in addition to those already mentioned,) were sulphuretted and phosphuretted hydrogen, phosphuret of lime, and camphor, caoutchouc, myrrh, ambergris, metallic soaps, fused potassa, solution of ammonia, nitric oxide gas, palm oil and whale and linseed oil ; and oils of tar, amber, petroleum, and orange peel.*

(h.) Concentrated muriatic acid extricates chlorine from the compound, and nitrogen is evolved by strong nitric acid.

(i.) *Composition and proportions.*—*The analysis has not been perhaps performed with the strictest accuracy, but by withdrawing the chlorine by the action of mercury, Sir H. Davy liberated nitrogen ; this compound consists therefore of these two principles, probably in the ratio of Chlorine, 4 proportions, $36 \times 4 = 144$*

Nitrogen 1

14

158 which is of course to be received as its representative number.†

Remarks.—This compound is a very singular one, and the fact of a fluid substance *exploding with heat, light, and strong force, when its elements are separating into the gaseous form*, is, as Sir H. Davy remarks, without a parallel, even in the case of euchlorine, (soon to be described,) which explodes indeed, into gases, but being a gas before, the fact is less extraordinary. The chloride of nitrogen is the more extraordinary, because nitrogen is itself so inert a body. We have seen however, in the case of the nitric compounds, that it becomes very active when in combination, and the present case, adds another instance to show how little we can, by reasoning a priori, determine what will be the properties of bodies in combination, and what the results of elementary action.

THE METALS *all combine with chlorine*, and several of them, either in leaves or powder, take fire in this gas spontaneously ; gold, silver, and Dutch metal, in leaves, and antimony, arsenic and bismuth, in powder.

* Nicholson's Journal, Vol. XXXIV, p. 180.

† Messrs. P. W. and E. suggest that hydrogen is one of the the principles of this compound, but this opinion has not been adopted by other chemists.

A tall jar, or trumpet-shaped tube, closed at one end, is filled with chlorine gas, and stopped by a cork, or covered by a glass. Either of the three metals last named, or the sulphuret of the first, will usually take fire, and form a shower, if introduced in powder; and a white chloride, if the materials are dry, or a muriate if they are moist, is produced.

COMPOUNDS PRODUCED BY THE ACTION OF CHLORINE UPON THE
ALKALIES AND EARTHS AND THEIR BASES.

Remark.—These bodies are possessed of wonderful properties, and some of them perform a great part in chemistry, and the arts. It is owing to the decomposition of one of them, (that produced by the action of chlorine upon potassa,) that we obtain the chloric oxides and acids, which, in strictness of logical order, should be described before any of the chlorates; but for the benefit of the learner, I have preferred that order which appears best adapted to a clear comprehension of the subject; this being a much more important and difficult object to attain than to construct a tabular arrangement for an adept.

The only fact that is necessary to be stated, to render the history of the bodies now to be described intelligible, is that there exists in them an acid, the chloric, of which chlorine is the basis, and that oxygen exists in this acid in great proportion. This is agreed on all hands, both by the advocates of the compound and simple nature of chlorine.

As soon as we have described the compound of chlorate of potassa, we can describe the chloric acid and oxides.

CHLORATES.

General characters.

1. Afford very pure oxygen gas when exposed to a red heat.
2. Deflagrate violently with combustibles.
3. Detonate by percussion, and sometimes spontaneously, when mixed with inflammables.
4. Cause them to burn, when mixed with this salt, and nitric or sulphuric acid is added.
5. Taste, cool and penetrating.
6. Soluble and crystallizable—generally soluble in alcohol.
7. Formed by passing chlorine gas through the base, dissolved or suspended in water.
8. Also, by adding liquid chloric acid to the base.
9. Unknown till 1786—do not exist as natural productions.
10. Most of the chlorates contain one equivalent of chloric acid, and one of protoxide, and therefore the oxygen in the former, is to that in the latter, as 1 to 5.—*Turner.*

CHLORATE OF POTASSA.

1. HISTORY.—First accidentally formed by Dr. Higgins,* who supposed it to be nitre. Berthollet is justly regarded as the true discoverer, (in 1786.) Mr. Chenevix presented an excellent memoir upon it, to the Royal Society, A. D. 1802.

2. PREPARATION.

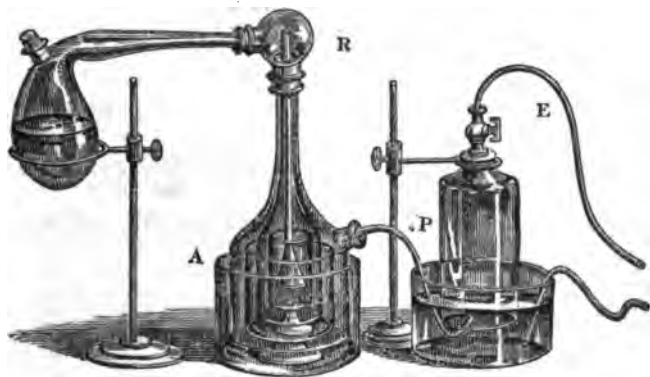
(a.) *Solution of caustic potash is placed in Woulfe's bottles, and a stream of chlorine gas passed through it; there should be a vessel to catch impurities between the retort or flask, and the first Woulfe's bottle.*

(b.) *A concentrated hot solution of pearl ashes† is allowed to stand till cold, that the sulphate of potassa may precipitate, and it is then saturated with chlorine gas, without first rendering it caustic. The effervescence towards the end, and the yellow color of the solution indicate saturation. An enormous quantity of gas is absorbed; a lead pot is convenient for obtaining the gas, and a lead tube for the communication with the first bottle. I have never observed that the admission of light made any difference in the formation of the chlorate, as asserted by some authors.‡*

* See Higgins on Acetous acid, p. 180.

† When carbonate of potassa is employed, the chlorine displaces a part of the carbonic acid which combines with another part of the alkali to form bi-carbonate, which, especially with a concentrated alkaline solution, is obtained in crystals mixed with the chlorate; this is in fact the condition of much of the chlorate of potassa of commerce, as is proved by the addition of a little weak muriatic acid. J. T.

‡ *Apparatus to facilitate the absorption of gases.—Dr. Hare.*



"After the apparatus has been once put together, there is no juncture to be made in order to employ it, excepting that of the retort with the neck of the receiver, R. The other junctures will serve for any length of time, during which the glass may remain unbroken."

"Suppose the three concentric jars, of which A is the outer one, to be supplied with the liquid to be impregnated, the bells and trumped shaped tube being situated as the figure represents them; also that a cork has been perforated for the reception of the beak of the retort, and inserted into the mouth of the receiver, R. In order to put the apparatus in operation, it will then only be necessary to introduce

Much muriate of potassa is produced, and but a small proportion of the chlorate, which is often mixed with siliceous earth separated from the alkali, in which it existed as an impurity. As the muriate of potassa is much more soluble in water than the chlorate, we dissolve the precipitated salt in hot water, filter and crystallize anew, and sometimes this is done twice before the salt is pure. Another crop of crystals, but less pure, may be obtained by evaporating and cooling the original solution, which finally yields only muriate of potassa.*

Into the retort the generating materials, fasten the beak into the mouth of the receiver, and apply heat, if requisite. On inspecting the figure, it will be sufficiently evident, that any gas, generated in the retort, must pass into the receiver. Having, in this, deposited any accompanying vapor, the gas must proceed by the trumpet shaped tube, until it reaches the liquid in the innermost jar. If it be not all absorbed, in this jar, it must escape through the liquid in it, and reach another portion of the liquid between the innermost jar and the next one. If not absorbed by this portion of the liquid, with a sufficient degree of rapidity, it must depress it, until its surface coincides with the narrow part of the stem, which supports the jar. Of course, the pressure and the surface, exposed for impregnation, will be very much increased. Should the supply of gas still exceed the absorption, the excess, after filling the inner bell glass, will escape to the next bell glass, and depress the liquid, in the outer jar, exactly in the same manner as described with respect to the intermediate jar. The degree of this depression, will depend on the depth to which the recurved pipe, P, is sunk in the adjoining vessel; for as soon as the pressure within is sufficient to displace a column of water equal to that in this tube, an escape of the gas must take place from its orifice."

"The bell glass, over the recurved tube, being previously filled with water, may be employed to catch the excess of gas, while by the syphon, the water descending from the bell is conveyed into another vessel, so as to be productive of no inconvenience."

"By extending the pipe, E, proceeding from the top of the bell glass, any gas, which is not absorbed, may be conducted into a bladder, or under a large vessel, filled with water, and inverted over the pneumatic cistern."

* It is important in this case and in others, to retain the heat of a hot solution, while it is filtering, that no part of the contents may crystallize prematurely on the filter, and be thus mixed with impurities. For this purpose, Dr. Hare contrived the apparatus represented in the annexed cut. It is made of sheet tin, and contains one funnel of that metal, destined to support a glass filtering funnel with its paper filter, and another funnel with the vertex upward, as seen at *a*, and intended to act as a chimney, to the Argand lamp below, which keeps the water or other fluid hot, that fills the cavity which is made tight for this purpose, and thus the liquor filters without being cooled. After the saturated solution of chlorate of potassa, made with boiling hot water, passes the filter, "the chlorate separates in crystalline plates of a silvery whiteness, which, during their subsidence, are beautifully iridescent."



principles, existing in the salt in a condensed state, and yet held by so feeble an affinity that they are easily disengaged.

(a.) *In the old theory* it was supposed that *the chlorine* (oxy-muriatic acid,) was, during the combination with the base, *in part decomposed, one large portion of it giving oxygen to the other*, made it a super or hyper oxygenized muriatic acid, which combined with a part of the base to form the peculiar salt, while the muriatic acid, remaining from the disoxygenation of a part of the oxy-muriatic acid, combined with the remainder of the base, and thus formed the muriate of potassa so abundantly produced in this process.

(b.) *Now*, the phenomena are accounted for *by the aid of the decomposition of water, whose oxygen being added to the chlorine forms chloric acid*, (soon to be described,) and this acid combines with a part of the base to form chlorate of potassa: *while the hydrogen of the water uniting with the remainder of the chlorine forms muriatic acid*; and this, with the remainder of the base, forms muriate of potassa. Upon this supposition, the alkali does not undergo decomposition, but is wholly divided between two acids, the muriatic and the chloric, both of which are formed in the process.

(c.) *According to another view, the alkali undergoes decomposition, and a part of its oxygen is transferred to another part to turn it into peroxide, which is supposed to combine with the chloric acid, produced by the decomposition of water, and the muriatic acid generated in the same way forms a muriate*;* or, the salt produced may be regarded not as a compound of chloric acid and peroxide of potassium, but as a triple compound of oxygen, chlorine, and peroxide of potassium.†

The decomposition of the salt gives 6 proportions of oxygen, 1 of potassium, and 1 of chlorine; and as to this, there is no difference of opinion; but Gay-Lussac and Davy, whose views are, on this subject as well as on others connected with chemical science, entitled to peculiar respect, differ in the arrangement of the elements. I quote the following statement from Dr. Henry. (Vol. I. p. 534.)

* But, with what? Not with the protoxide, for that is by the supposition in part decomposed to form the peroxide which *covers and is identified with* the remainder of the protoxide, and it is not supposed that the muriatic acid can unite with potassium which would result from the decomposition of the protoxide. Chlorine would indeed unite with potassium, but being in solution in water it must be immediately turned into a muriate.

† It is impossible that the peroxide of potassium should exist in the chlorate; heat expels only six atoms of oxygen, and leaves chloride of potassium—now five of these must come from the acid and one from the alkali. It may be said, (by those who, with Berzelius, believe that chlorides may exist in solution without decomposition,) that the 5 atoms of potassa are decomposed, liberating enough oxygen to produce 1 atom chloric acid, which will immediately form chlorate of potassa, with some of the undecomposed alkali. The 5 atoms of potassium likewise combine with 5 of chlorine, and form 5 atoms chloride of potassium. Hence for every atom of chlorate of potassa, (or 124 parts,) there must be 5 atoms of chloride of potassium, (or 280 parts = 425 muriate of potassa,) produced.—J. T.

According to Davy,

Chlorates consist of $\left\{ \begin{array}{l} 1 \text{ atom of metallic base,} \\ 1 \text{ atom of chlorine,} \\ 6 \text{ atoms of oxygen.} \end{array} \right.$

According to Gay-Lussac,

Chlorates are $\left\{ \begin{array}{l} 1 \text{ atom of alkaline} \\ \text{base, consisting of} \end{array} \right\} \left\{ \begin{array}{l} 1 \text{ atom of metal,} \\ 1 \text{ atom of oxygen.} \end{array} \right.$
 composed of $\left\{ \begin{array}{l} 1 \text{ atom of chloric} \\ \text{acid, consisting of} \end{array} \right\} \left\{ \begin{array}{l} 5 \text{ atoms oxygen.} \\ 1 \text{ atom of chlorine.} \end{array} \right.$

It is obvious that the two views do not differ at all in the statement of the elements, and in the number of proportions of each ; but Davy's view presents a triple compound, of three elements, without implying the existence either of acid or alkali ; while Gay-Lussac's divides the oxygen, 1 proportion of which, with the potassium, forms the alkaline base, and the other 5 along with 1 of chlorine, form the chloric acid.

This view is fortified by the actual existence and composition of the chloric acid, (as will presently appear,) and I am disposed, in conformity with general practice, to give it a decided preference. This is the view expressed under (b.) of the present head, 4. Upon either view, the equivalent number of chlorate of potash is 124 ; for chlorine 1, 36 + potassium 1, 40 + oxygen 6, 48 = 124.

5. USES.

(a.) *In chemistry*, to afford pure oxygen gas—to oxygenize metals and combustibles—to analyze vegetables, to afford the oxides and acids to be mentioned under the next head, and to demonstrate the energy of elementary action, by numerous and various experiments.

(b.) *In medicine*.—Believed to be an active remedy, but its medicinal powers seem not to be accurately ascertained.

(c.) *In the arts, &c.*—*Matches* for kindling without fire are made by mingling dry triturated chlorate of potassa 2 parts, with powdered sulphur 1 part ; or powdered sugar 2 parts, with powdered chlorate of potassa 1 part, always pounded separately, and mingled by very gentle movement, as of a feather ; either of these mixtures being moistened into a paste, by mucilage, sulphur matches are rolled in it, and dried. When wanted for kindling a light, they are dipped into a small bottle containing fibres of amianthus, or of spun glass, imbued with sulphuric acid ; the theory of the action is obvious.

The percussion powder used to discharge fire arms, is a mixture of dry chlorate of potassa, and sulphur, or other combustibles, and (as is said,) recently of fulminating mercury ;* still in a train, fulminating mercury does not fire gunpowder, but merely silvers the

* Dr. Hare's Compendium, p. 247.

grains and throws them aside. Gunpowder, however, sets fire to fulminating mercury.

(d.) *In war—to form a gunpowder, &c.*—Were this salt as cheap as nitre, and could it be used with safety, it would be a tremendous agent. Happily, however, both these difficulties will prevent its introduction, either in the form of chloric gunpowder, or of a mixture with various inflammables, and especially phosphorus, with which its action is very violent, insuring both explosion and combustion, incoercible, except by immersion in water.*

OXIDES OF CHLORINE AND CHLORIC ACID.

Remark.—These subjects, usually arranged with chlorine, are introduced here, because the oxides and acid are obtained by the agency of the chlorate of potassa, and it is difficult to explain the phenomena of their production, without a previous knowledge of this salt.

PROTOXIDE OF CHLORINE.—EUCHLORINE OF DAVY.

1. *DISCOVERY.*—By Sir H. Davy, in 1811, and described in the Phil. Trans. for that year.

2. PREPARATION.

(a.) *Muriatic acid, diluted with an equal volume of water, is added to chlorate of potassa in a retort, till the salt is completely covered; a very mild heat is applied, and the gas is received over mercury.*

This process is troublesome; the chlorine that comes over with the oxide, corrodes the mercury, and soils and clouds the inside of the vessels, and they are often blown to pieces, as I have repeatedly experienced, even by the effect of the warmth of the hands employed in moving them.

(b.) *I have obviated these inconveniences, by placing the chlorate of potassa and muriatic acid, diluted by an equal volume of water, in a small glass flask, furnished with a glass tube, bent twice at right angles, and passing to the bottom of any clean dry phial, flask, or tube, rather deep, and with a narrow neck;† a mild heat as of a water bath, or a spirit lamp, disengages the gas, which, by its superior gravity, displaces the common air, and occupies its place. By using the curved tongs, mentioned on p. 500, Vol. I. the vessels are easily lifted without touching them by the hands;‡ any substance*

* It was not without some reason that Fourcroy remarked that this salt contains the elements of thunder in its composition. An attempt was made in 1806, to introduce projectiles, charged with chlorate of potassa and phosphorus, into warfare, for the purpose of burning a flotilla; but happily it failed by accident, although it acted with the energy that might have been expected. The obvious danger to those who employ this preparation, will probably prevent its use in war.

† Nearly as at (c.) p. 2.

‡ In the common method of operating, I did not often get through without an explosion: the mere movement of the retort, however gentle, is sufficient to produce it, but in the method described under (b.) I have never met with an accident. The recurved tube may also be used for impregnating water with the gas; it soon acquires its peculiar rich yellow color, and requires neither cold, agitation nor pressure.

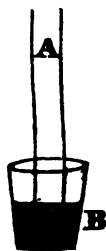
can then be, in the same manner, introduced, or they can be transferred to the mercurial cistern, and all the experiments are neatly performed, without any danger to the operator.* Another method which succeeds pretty well, is represented below.

(c.) A, is a tall tube, containing chlorate of potassa, and muriatic acid, very little diluted.

B, a glass of hot water.

The euchlorine gas rises and displaces the common air, showing a very deep yellow color.

A rag imbued with spirits of turpentine,† and fixed to a pole, will fire with a slight explosion, on being held so as to touch the gas.



3. PROPERTIES.

(a.) *It has a dense yellow color, much deeper, and more brilliant, than that of chlorine; hence it was called euchlorine, from the Greek intensive particle, εὖ, and χλωρος. Smell a little like that of burnt sugar mixed with chlorine; does not irritate and distress the glottis and lungs like chlorine.‡*

(b.) *Water dissolves 8 or 10 volumes of the gas, and acquires its peculiar color.*

(c.) *Destroys vegetable colors, but gives first a tint of red.*

(d.) *Explodes by a gentle heat, and by the contact of all burning bodies.*

(e.) *Phosphorus, and volatile oils, alcohol and ether, in the cold, cause an explosion and combustion; the fluids may be introduced on a rag, held by tongs.*

(f.) *With nitric oxide gas, it produces dense red fumes, with a diminution of volume.*

(g.) *Sp. gr. 2.4; 100 cubic inches weigh 74.55 grains.*

(h.) *Condensable into a fluid, by extreme cold and pressure.—*Mr. Faraday§ enclosed some of the chlorate of potassa and sulphuric acid, in a glass tube, and left them to act for 24 hours, when the heat of 100° was applied to the materials, and the cold of 0 to the other end of the tube. A fluid was obtained, of a deep yellow color. On attempting to open the tube, it burst with explosion, and there was a rush of euchlorine gas.

* Am. Jour. Vol. VI, p. 195. It is true that the gas may, in this way, contain a little chlorine, or common air, but it is pure enough for every common demonstration. The best proportions are, of the salt 2, strong muriatic acid 1, and 1 water. Dr. Turner says that if the chlorate is mixed with an excess of muriatic acid, it is completely decomposed.

† There should not be so much of the fluid as to drop from the rag, because it may then produce a violent explosion.

‡ We anxiously avoid permitting chlorine to flow into the room at all, but this gas, although not agreeable, occasions, when floating about, no serious inconvenience to the lungs.

§ Phil. Trans. 1823, p. 194.

"The chlorine is subsequently absorbed by the mercury."

Combustibles burn in euchlorine gas after it is decomposed by heat, as they would do in a mixture of 2 volumes of chlorine, and 1 of oxygen gas.

No good reason has yet been given, why heat and light are evolved, in consequence of the separation of two gases, into a larger volume; theory would have taught us to expect rather the production of cold.

PEROXIDE OF CHLORINE.

1. **DISCOVERY**—By Sir H. Davy;* and not long after, examined by Count Stadion, of Vienna.†

2. PROCESS.

(a.) *For the sake of safety, not over 50 or 60 grs. of the dry powdered chlorate of potassa are mixed with a little sulphuric acid, and rubbed with a spatula of platinum till they are thoroughly incorporated into a paste of a bright orange color.*

This is introduced into a small glass retort, and gradually heated by a water bath, containing alcohol, to prevent the fluid from attaining the temperature of 212° ; and great care should be taken, that no combustible substance is mingled with the materials. At first, dense white fumes, and a little of an orange gas are disengaged, without heat, but most of the peculiar gas remains combined with the solid materials. Count Stadion poured strong sulphuric acid over a small quantity of the chlorate of potassa fused in a retort, and gradually heated the retort for three hours, till it reached the temperature of 212° .

The gas is received over mercury, upon which it does not act in the cold.‡

3. PROPERTIES.

(a.) *Color bright yellowish green, but much more brilliant than that of the protoxide; much more rapidly dissolved in water, which absorbs 7 volumes of the gas, and acquires the same tint; the protoxide however absorbs 8 or 10 volumes, but more tardily. The solution is fuming; not acid, but corrosive, and leaves for a long time, a disagreeable impression on the tongue. The solution is decomposed in the light into chlorine and chloric acid, but is permanent in the dark.*

(b.) *Odor, peculiar and aromatic, unmixed with that of chlorine.*

* Phil. Trans. 1815, Part II.

† Thomson's Annals, Vol. IX. p. 22. As this gas is obtained by the same hazardous process as that which exposed Mr. Chenevix and his assistant to great danger, (See page 30), it should never be attempted without the most anxious attention, and never by an inexperienced person.

‡ I have not made the experiment, but cannot doubt that this gas may be collected without mercury, in the same manner as that described under the protoxide.

(c.) *Destroys most vegetable colors*, without previously reddening them, but Count Stadion asserts that it does not change blue paper.

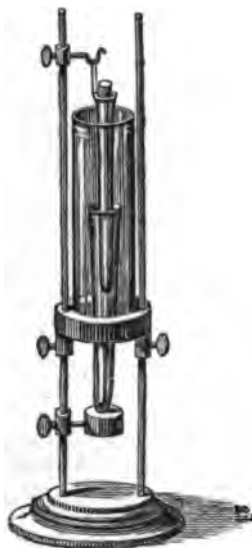
(d.) *Heated to about 212° (Davy) 112° to 114° (Stadion) it explodes with bright light, and with more violence than euchlorine, and is much more expanded.*

(e.) *By explosion 40 volumes of the gas became 60, of which 20 are chlorine, and 40 oxygen,* as every volume of oxygen represents two equivalents, the proportions of this peroxide are therefore 1 chlorine 36 + 4 oxygen, $32=68$ for the equivalent number.* As the protoxide of chlorine consists of chlorine 1 proportion, and oxygen 1, it is obvious that there may be two other oxides between that and the peroxide, namely, one of 1 chlorine and 2 oxygen, and another of 1 chlorine and 3 oxygen, and this latter seems to have been obtained by Count Stadion, unless we may suppose that his gas was in fact a mixture of the two oxides which we have described.

(f.) *Sp. gr. 2.36; it does not promptly combine with alkalis, but after a time produces with them chlorates, with probably a small portion of muriates.*

(g.) *Phosphorus alone among the combustibles, causes in the cold, a spontaneous combustion; it burns with great brilliancy, in the mixed gases arising from the decomposition of this gas.*

This gas, the peroxide of chlorine, may be obtained by the action of the nitric acid on the chlorate of potassa; and a much larger proportion of nitric acid may be safely used than of the sulphuric; but the gas is mixed with about $\frac{1}{2}$ of oxygen.



* *Apparatus for exhibiting safely the explosion of peroxide of Chlorine.—Dr. Hare.*

"The annexed figure represents an apparatus for exhibiting, without danger to the spectators, the detonation of the peroxide of chlorine.

"Into a tube, supported on a table in a position inclined from that in which the operator stands, about an eighth of an ounce of sulphuric acid is introduced. Chlorate of potassa in powder is added gradually in very small quantities, till a paste is formed, of an orange color.

"The tube being thus charged, it is corked gently, and suspended within the stout cylinder, as in the drawing. It is then surrounded, near the bottom, by another tube, supplied with boiling water. At first, the hot water is applied only to that part of the tube which contains the paste: but, as soon as the inner tube is pervaded by a greenish yellow color, demonstrating the evolution of the gaseous oxide, the outer tube containing the water is to be raised, so that the gas may be generally heated by it.

"An explosion soon follows, from the influence of which spectators are protected, by the glass cylinder."

CHLORIC ACID.

1. DISCOVERY.—*Indicated by Mr. Chenevix, in 1802, (see his memoir,) but first distinctly exhibited by Vauquelin and Gay-Lussac.**

Remark.—I shall anticipate so far as to mention now, the chlorate of baryta, and to say that it is obtained by passing chlorine gas through a warm aqueous solution of pure baryta, till it is saturated; the filtered solution is then to be boiled with phosphate of silver,† which will decompose the muriate of baryta that is mixed with the chlorate, and phosphate of baryta, and muriate of silver, two insoluble salts will be precipitated. Care must be taken that there is no excess of phosphate of silver.‡

2. PROCESS.—*Solution of pure chlorate of baryta with sulphuric acid, gives a precipitate of sulphate of baryta liberating chloric acid.* There must be no excess either of sulphuric acid or of chlorate of baryta; this will be the fact when these agents cause no precipitate in separate portions of the fluid, which should remain perfectly transparent.

3. PROPERTIES.

(a.) *A colorless liquid; inodorous, except when concentrated and heated, when it is immoderately pungent.*

(b.) *Sour, reddens blue colors, does not bleach promptly, but after a day or two destroys the color of litmus paper, especially if suspended in the air.*

(c.) *Does not precipitate nitrate of silver, lead or mercury.*

(d.) Concentrated by a gentle heat, and assumes an oily consistence; with a higher heat partially volatilized, and decomposed into chlorine and oxygen; after which, on account of the formation of muriatic acid, it precipitates nitrate of silver; does not lose weight in the air.

(e.) *Decomposed by muriatic acid, and both acids, if mingled in proper proportions, are changed into chlorine; the oxygen of the chloric acid uniting with the hydrogen of the muriatic acid to form water, and thus evolving chlorine from both; or, as would have been said upon the old theory, the excess of oxygen in chloric acid beyond what is in oxy-muriatic acid, producing that body by uniting with the muriatic acid, and evolving it from the chloric acid.*

* Ann. de Chim. Vol. XCV. p. 102.

† An insoluble salt, easily obtained by mingling a solution of nitrate of silver with one of phosphate of soda, when nitrate of soda and phosphate of silver are produced, and the nitrate remains in solution.

‡ See phosphate of baryta.

(f.) *With sulphuretted hydrogen, forms water and liberates chlorine and sulphur*; with sulphurous acid, forms sulphuric acid and evolves chlorine.

(g.) *The metals that decompose water, also decompose the chloric acid*, and form compounds consisting of chlorine and a metallic oxide.

(h.) *Forms chlorates with alkalis*; that is, salts perfectly analogous to those produced by passing chlorine gas through the bases dissolved or suspended in water; this fact removes the possibility of a doubt with respect to the nature of the chloric acid.

(i.) *Constitution*.—Mr. Chenevix, in 1802, inferred from the decomposition of chlorate of potassa by heat, that the acid which he supposed to exist in it,* consisted of chlorine 35, and oxygen 65, while he supposed chlorine itself to contain only 16 per cent. of oxygen.

Vauquelin drew the same conclusion, as to the constitution of chloric acid; but Gay-Lussac supposes it to consist of chlorine 47.3, and oxygen 52.7. This Dr. Henry regards as the more probable constitution, as it gives chlorine 47.3, and oxygen 52.7, or chlorine 1 proportion, 36, + oxygen 5, 40=76, the equivalent number of chloric acid.

PER-CHLORIC ACID, AND PER-CHLORATE OF POTASSA.

1. *DISCOVERY AND PREPARATION*.—By Count Stadion, who found, that after the process for per-oxide of chlorine is through, there remains in the retort a mixture of bi-sulphate of potassa, and per-chlorate of potassa. The bi-sulphate is removed by washing with cold water, and the per-chlorate remains. It is soluble in not less than 50 or 55 parts of water, at 60°, but dissolves easily in boiling hot water. It crystallizes in lengthened octahedra. It does not change vegetable colors. Heated with an equal weight of sulphuric acid, to 280°, white vapors arise, which condense into a colorless fluid, and are regarded as *per-chloric acid*. Its properties are but little known. Count Stadion, by decomposing the salt at 412°, obtained chloride of potassium, (dry muriate of potassa,) and oxygen gas, the latter in such quantity as to induce him to fix the proportions at chlorine 1 equiv. 36, + oxygen 7,† 56=92, for the equivalent number.

* Called at that time, the super or hyper-oxygenized muriatic acid.

† 8 equiv. according to the Lib. of Use. Knowledge.

The per-chlorate of potassa may be formed by mixing 1 part of powdered chlorate of potassa with 3 of strong sulphuric acid, and heating the mixture till it turns white, when the mass will be found to consist of bi-sulphate and per-chlorate of potassa.*

REMARKS ON THE COMPOUNDS OF CHLORINE AND OXYGEN, AND ON THEIR DECOMPOSITION.

Gay-Lussac† gives the two first columns of the following table, to which the third is now added.

	1 propor. of chlorine.	Oxygen.	Equivalent number.
Protoxide of chlorine,	36 +	8, one propor.	= 44
Peroxide of chlorine,	36	32, four	68
Chloric acid,	36	40, five	76
Per-chloric acid,	36	56, seven	92

Chlorine exists no where naturally, in a free state, nor do the compounds named in the above table, exist at all in nature.‡ We cannot directly combine their elements by art, and the mutual affinity of oxygen and chlorine being extremely feeble, and it being still very energetic towards combustibles, the chloric acids and oxides act on these bodies with great violence.

Remarks.—We are now prepared to understand the phenomena that attend the action of the acids upon the chlorate of potassa. They combine with the base and liberate the chloric acid in a decomposed state, giving different proportions of chlorine, oxygen, and the two oxides of chlorine, already discovered; and possibly of others not yet ascertained.§ The decrepitation and explosions arise from the decomposition of the chloric acid and oxides; and we have seen that the oxygen and chlorine of the latter, separate with explosion even when the gases, without decomposition, are previously obtained in a free state.

In the case of muriatic acid, concentrated and in excess, the chloric acid, separated by it from the chlorate of potassa, is completely decomposed; its five proportions of oxygen unite with the one proportion of hydrogen in five of muriatic acid that are decomposed, and form five proportions of water, while the chlorine of both is disengaged. But if the salt is in excess, and the acid diluted, the chloric acid is deprived of a part of its oxygen only—water is formed, and the chlorine and protoxide of chlorine are evolved in the gaseous form. In the case of sulphuric acid, when it decomposes the chlorate of potassa, the chloric acid is also decomposed into peroxide of chlorine and oxygen, which last probably attaches itself to some portion of

* See Ann. de Chim. et de Phys. Toms. VIII and IX.

† Ann. de Chim. et de Phys. Tom. IX.

‡ That is, as far as we know.

§ There is obviously room for two oxides of chlorine between the protoxide and the peroxide, and they would contain, the one, 2 equivalents of oxygen = 16, and the other, 3 = 24.

the acid of the undecomposed chlorate of potassa, and turns it into per-chloric acid, and the salt in which it is, into a per-chlorate, and thus the whole product is bi-sulphate and per-chlorate of potassa, and peroxide of chlorine.*

CHLORATE OF SODA.

We are indebted to Mr. Chenevix, for nearly all that we know of this salt.

1. PREPARATION.

(a.) *Formed in precisely the same manner as the preceding species*; but being nearly equally soluble with common salt, which is formed in the same process, it is next to impossible to separate them by crystallization. The chlorate is soluble in alcohol, but so also, according to Mr. Chenevix, is the muriate of soda,† especially when accompanied by the chlorate. With abundant materials and by repeated crystallizations in alcohol, Mr. Chenevix, (1802,) obtained a little of the salt pure.

(b.) *The inconveniences are avoided by saturating the pure chloric acid*, either with soda or its carbonate, when the salt is at once obtained pure.

2. PROPERTIES.

(a.) *It crystallizes in cubes or in obtuse rhomboids*; taste cold and different from that of common salt.

(b.) *Affected by heat, by combustibles and by acids, precisely as the former species.*

Potassa is the only base which decomposes this salt.

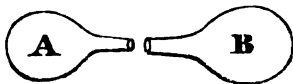
3. COMPOSITION.—According to Mr. Chenevix, soda, 29.6, chloric acid, 66.2, water, 4.2=100.0, or by theory, soda 32, and chloric acid 76=108.—*Brande.*

These numbers, if the weight of the water is added to the acid, and the salt considered as anhydrous,‡ are very near the proportions of Mr. Chenevix.

CHLORATE OF AMMONIA.

1. PREPARATION.

(a.) *It is impossible to form this salt by a direct combination of its principles*; for, if chlorine gas and ammoniacal gas are mingled in a glass vessel, there is a double decomposition with flame, and nitrogen and muriate of ammonia are obtained, the latter in snow white clouds. The annexed apparatus shows this fact well. A, is ground to fit B; A is filled with chlorine gas, and B with the gas ammonia; put them together and turn the chlorine uppermost; there is always a white precipitate, sometimes with flame.



* Turner's Chem. 2d Ed. p. 283.

† This is in opposition to the opinion of all preceding authors.

‡ Phil. Trans. 1802.

(b.) *With a strong aqueous solution of ammonia and chlorine, there is a lively effervescence*; the products are the same as before, the muriate of ammonia is dissolved, and the nitrogen is easily collected as a gas. This is well performed by filling a long tube closed at one end, half full of a strong aqueous solution of chlorine, then adding the liquid ammonia, and with a finger on the mouth, quickly inverting the tube in a cup of water, when the nitrogen rapidly collects at the top of the tube.

(c.) *If to a pint receiver of chlorine gas, we add half a drachm of strong solution of ammonia, an explosion sometimes follows*; or, invert a 4 oz. bottle of the gas in 4 oz. measures of strong liquid ammonia, and there results an absorption with white fumes, and it may be, even a detonation.

The present theory of these experiments is, that chlorine unites with the hydrogen of the ammonia, and forms muriatic acid, while the nitrogen of the ammonia is liberated. The old theory was, that the oxygen of the oxy-muriatic acid formed water with the hydrogen of the ammonia, and thus liberated both muriatic acid and nitrogen.*

(d.) *Since the discovery of chloric acid, it has become easy to form this salt, by saturating the acid with ammonia or its carbonate.*

(e.) Or, by double exchange, by mixing a chlorate of either of the earths with carbonate of ammonia; the earthy carbonate is precipitated and the chlorate of ammonia remains in solution.

2. PROPERTIES.

(a.) *Obtained in acicular crystals, which are very soluble in water and in alcohol; decomposed at a very low temperature, and gives out a large quantity of aerial matter, with a smell of the chloric gases.*

(b.) *Very volatile*; on ignited coals, detonates with a red flame; the exact proportion of its principles is unknown.

(c.) *It is said to be a self-detonating salt at the temperature of ignition, and to produce energetic effects with combustible substances.*

As its constitution embraces two supporters of combustion, and one very combustible element, we should of course expect that it would be a very active substance.

3. COMPOSITION.—By theory, ammonia 17, + chloric acid 76.—*Brande.*

CHLORATE OF BARYTA.

1. PROCESS.

(a.) *Warm aqueous solution of pure baryta, in Woulfe's bottles; saturate with chlorine gas*; form a phosphate of silver by mingling, to mutual saturation, nitrate of silver and phosphate of soda; the phosphate of silver is precipitated; boil this with the chloric solution of baryta, the object being to decompose the muriate of baryta that is formed at the same time with the chlorate of that earth; thus mu-

* In both cases, if there be an excess of ammonia, the muriate of that alkali will be also formed.

riate of silver and phosphate of baryta, both insoluble, are precipitated, and the chlorate of baryta is left in solution. If the muriate of baryta has all been removed, there will be no precipitate when nitrate of silver is added, and if there is a precipitate, then the fluid must be boiled with more phosphate of silver; if there has been too much phosphate of silver added, it will be discovered by adding a few drops of muriatic acid, and if ascertained, it must be removed by adding more of the original filtered chloric solution, reserved for the purpose.

—Henry.

(b.) Another method of preparing this salt is recommended by Mr. Wheeler.* *Condense fluo-silicic acid gas in water; with this, in slight excess, digest, for a few minutes, chlorate of potassa; an insoluble double fluuate of silica and potassa is precipitated, and the chloric acid remains in solution; this is neutralized by carbonate of baryta, which also throws down the excess of fluoric acid and silica, and then the chlorate of baryta is obtained by evaporation and crystallization.*

2. PROPERTIES.

(a.) *Crystals, prisms of four sides; taste pungent and austere; soluble in 4 parts of water at 50°.*

(b.) Neither nitric nor muriatic acid troubles the pure solution.

(c.) *By ignition loses .39 and leaves a residuum, doubtless the earth baryta.*

(d.) *Composition, by calculation, 1 acid, $76 + 1$ earth, $78 = 154$; or, acid $49.4 +$ earth $50.6 = 100$.—Henry.*

Vauquelin recommended, to dissolve the phosphate of silver in distilled vinegar and boil it with chloric solution of baryta, in order to purify it from muriate of baryta, but the process appears to be dangerous, as he met with a severe explosion;† obviously from the reaction of the chlorine and oxygen upon the combustible elements of the vinegar.

CHLORATE OF STRONTIA.

1. PREPARATION.—This may be prepared in the same manner as the chlorate of baryta; perhaps preferably by the action of chloric acid upon strontia or its carbonate.

2. PROPERTIES.—Taste astringent; deliquescent; gives a fine purple tint to burning alcohol.

3. COMPOSITION.—By theory, 1 strontia, $52 + 1$ acid, $76 = 128$.

CHLORATE OF LIME.

Remark.—This salt is often confounded with the chloride of lime, used in bleaching; that compound will be described under the chlorides and muriates; at present we advert only to the proper chlorate.

* Turner's Chemistry, p. 482.

† Ann. de Chim. Vol. XCI or XCV, p. 83.

1. PREPARATION.

(a.) *By passing chlorine gas, to saturation, through lime water, or better milk of lime, in Woulfe's bottles; the usual mixture of chlorate and muriate results, and as it is impossible to separate them, the muriate of lime is decomposed, by boiling with phosphate of silver, as already described with respect to baryta.*

(b.) *Or, it is easier to form it by the action of liquid chloric acid upon hydrate or carbonate of lime.*

2. PROPERTIES.

(a.) *Very deliquescent; readily undergoes the watery fusion.*

(b.) *Very soluble in alcohol; taste sharp, bitter and cold.*

(c.) *Composition, according to Mr. Chenevix, chloric acid 55.2, lime 28.3, water 16.5 = 100.*

(d.) *Decomposed by all the acids, and, with the strong ones, a flash of light more frequently appears, than with the alkaline chlorates.*

The chlorates of magnesia, alumina and the other earths, are little known, and probably would not present any properties different from those that have been discovered in the chlorates already described.

MURIATES* AND CHLORIDES.

Remarks.—The muriates were omitted, in their proper place, immediately after muriatic acid, and the reason has been already assigned, namely, that it is impossible, without a knowledge of chlorine, and its relations, to understand what is now meant by muriates and how they stand related to the chlorides.

The bodies concerned in chloric combinations, are

1. *Chlorine*, now generally admitted as elementary.

2. *Oxides of chlorine, two*; the protoxide and the peroxide, composed of chlorine and oxygen.

3. *Chloric and per-chloric acid*; composed of chlorine and oxygen.

4. *Muriatic acid*; composed of chlorine and hydrogen.

5. *Muriates*; composed of muriatic acid, and a base, which, except in the case of ammonia, is an oxide of a metal.

6. *Chlorides*; composed of chlorine and a metal, or of chlorine and a combustible.

7. *Chlorates*; composed of chloric acid and, (ammonia excepted,) of an oxide of a metal.

8. *A muriate is changed into a chloride by heat or by crystallization*; giving up hydrogen from the muriatic acid, and oxygen from the oxide, to form water; and leaving the chlorine in union with the metallic base.†

* Called hydro-chlorates by those who call the muriatic acid the hydro-chloric.

† This statement will not apply to the chlorate of ammonia.

9. *Dry muriates*, except that of ammonia, are generally* regarded as *chlorides*.

10. *Chlorine unites with metals and combustibles*; generally at common temperatures, and often with spontaneous combustion, and forms *chlorides*, as already stated.

11. *A chloride of a metal is changed into a muriate*, generally by the decomposition of water, the hydrogen of which, with the chlorine, forms muriatic acid, and the oxygen with the metal forms an oxide, and the two unite to form a muriate.

12. Thus, *dissolved chlorides* of the metals become *muriates*, by appropriating the elements of water. *A chloride of a combustible by solution, generally forms two acids*; the muriatic and another, composed of the combustible and the oxygen of the water.

13. *Chlorine, at ignition, expels oxygen from the fixed alkalis, and from the alkaline earths*, and takes its place to form *chlorides*; it acts upon most of the other metallic oxides in the same manner, and sometimes below a red heat.

14. *Chlorine also unites with some of the oxides and forms peculiar compounds*, to which no distinct name has been given; they might be called *chlorides of oxides*. The affinity is feeble, and remains active only at low temperatures, being always destroyed by ignition.

15. *Muriatic acid gas heated with certain metals forms chlorides*; the hydrogen being expelled, and the chlorine uniting with the metal.

16. The chlorides will be mentioned again in connexion with the metals, and other facts respecting them will be stated.

In the above statements I have adopted the prevailing theory, although there are some parts of it which may demand a doubt: I allude particularly to the changes that are supposed to take place between the chlorides and the muriates. For every practical purpose, the dry muriates are actually treated as if they always contained muriatic acid and the oxide of a metal, instead of being sometimes composed of chlorine and a metal. I shall therefore, still treat them as muriates and subjoin to each a notice of the corresponding chloride, with the relation between the two, and an account of their supposed transmutation.

MURIATES.—*Distinguishing Characters.*

1. Exist, some of them, both in the solid and fluid state, some in the latter state only.

2. Strongly contrasted with the nitrates, by being little affected by common combustibles† at any temperature.

3. The sulphuric acid disengages from them, muriatic acid with effervescence.

* The exceptions will be stated in their places.

† Potassium would, doubtless, decompose them all.

‡ Carbon excepted.

4. With the nitric acid they afford nitro-muriatic acid, (to be mentioned soon.)
5. Soluble in water, and most of them raise its boiling point.
6. By heat they melt and are either wholly or partially volatilized; generally without decomposition.
7. With nitrate of silver give insoluble muriate (chloride) of silver.
8. The first known, and the most important of the salts.

MURIATE OF POTASSA.

1. NAME.—From supposed medicinal virtues, and from the discoverer, formerly called *febrifuge* or *digestive salt of Sylvius*, and from a mistake concerning its origin, *regenerated sea salt*.

2. PREPARATION.

(a.) *By saturating potassa or its carbonate with muriatic acid, and evaporating for crystals.*

(b.) Produced as a residuum in some chemical operations.

3. PROPERTIES.

(a.) *Usually in cubes or parallelopipeds.*

(b.) *Taste bitter, which distinguishes it from common salt.* Sp. gr. 1.836.

(c.) *With heat, decrepitates, melts and is volatilized, losing only a little water.*

(d.) *Soluble in 3 parts of water at 60°, and in 2, at 212°. Crystals are obtained by cooling; but more perfect and larger by spontaneous evaporation.*

(e.) Decomposed by the sulphuric acid, giving muriatic acid gas. Among the alkalies and earths, baryta alone decomposes this salt.

4. COMPOSITION.—*It is agreed by all, that in solution, this substance is a true muriate.* In that view it is considered as composed of acid, one proportion 37, + potassa, one, 48=85, for its equivalent number; and per cent. it is composed of acid 36.57, + potassa 63.43=100, a result very near that obtained many years ago, by Mr. Kirwan, which was acid 36, and alkali 64.

5. USE.—*In the crystallization of alum, and it is manufactured for this purpose, from the waste leys of the soap makers.*

It exists in sea and mineral waters—in the ashes of some vegetables, and even in milk.—Fourcroy.

CHLORIDE OF POTASSIUM.

1. PREPARATION.

(a.) *Potassium, heated* in chlorine gas, burns more vividly than in oxygen, and chlorine is absorbed in the proportion of 1.1 cub. in. for 1 gr. of the metal, and forms a chloride.*

* Authors state that it burns spontaneously; perhaps it may, in thin pieces and in warm gas; but I have seen it gradually combine with the chlorine, without combustion, even when heated.

(b.) *Potassium heated in muriatic acid gas, detaches the chlorine, liberates hydrogen, and forms the same chloride.*

(c.) *The muriate of potassa, just described, is supposed, during its crystallization from its watery solution, to become a chloride, by a spontaneous and unperceived decomposition of both its acid and alkali, the hydrogen of the former, and the oxygen of the latter, being at the moment of crystallization, detached from their former connexion, and united to form water; which is added to that of the solution, while the chloride is precipitated in crystals.*

(d.) *The same thing is supposed to happen when the aqueous solution of the muriate is evaporated by heat, and the substance obtained quite dry, even without crystallization. Mere solution of the crystals or of the uncrystallized solid substance in water, as is supposed, converts them again into muriates, by a decomposition of water, which gives its oxygen to the metal to form the alkali, (oxide of potassium,) and its hydrogen to the chlorine, to form muriatic acid.*

2. PROPERTIES.—*The same in all respects as those of the dry muriate already described.* Indeed, it is said that this muriate cannot exist except in solution. Still, the taste of the solution and of the crystal is the same, notwithstanding the wide difference in their constitution. Probably, however, as the substance tasted would not be sapid without moisture, it would be regarded, not as chloride, but as a muriate, the saliva furnishing the elements necessary for its conversion.

3. COMPOSITION.—Sir H. Davy considers this chloride as composed of 1 proportion of potassium, 40, and 1 of chlorine, 36 = 76, for its equivalent number.

This would give its composition, per cent. as 53 potassium, and 47 chlorine, nearly.

CHLORIDE OF POTASSA—(Chloride of oxide of potassium.)

A compound of chlorine and this alkali, is supposed to be obtained when chlorine is condensed by a *dilute and cold* solution of potassa; the alkaline properties are neutralized, but it cannot be obtained solid; for, as soon as it is concentrated, it is in part decomposed, to form chlorate of potassa and muriate of potassa; water probably affording the elements, and giving hydrogen to part of the chlorine to form muriatic acid, and oxygen to another part, to form chloric acid.

This chloride bleaches as readily as an aqueous solution of pure chlorine, and it is decomposed by animal and vegetable coloring matters, also by acids, even the carbonic in the atmosphere, and by heat.*

* Ann. de Chim. et de Phys. Tom. XVII.

I have often observed that in the usual process for chlorate of potassa, the fluid becomes colored like chlorine, when saturation takes place and not before; it then

MURIATE OF SODA.

1. HISTORY AND NAME.—*Known from the remotest ages; familiarly called salt.* This word, when used alone, always means *muriate of soda*, and all our ideas of saline bodies have been derived from this species.*

Often named, common, table and culinary salt, and when dug out of the earth, *mineral and rock salt; sea and marine salt*, when extracted from the ocean, &c.

2. PREPARATION.

By saturating soda, or its carbonate, with muriatic acid, but this is never done, except for instruction, and in analysis; as immense quantities of it are manufactured from natural sources.

The salt of commerce contains the muriates of lime, magnesia,† and potassa, and sulphate of lime, and sulphate of magnesia. Muriate of baryta will decompose the sulphates, and the carbonate of soda the earthy muriates. The precipitate being separated by a filter, the salt crystallizes by evaporation.

3. PROPERTIES.

(a.) *The common and primitive form is a cube*; the cubes sometimes adhere at their edges, forming a hollow pyramid, or hopper.

(b.) *Taste, that which we are accustomed to call purely saline*; but our impression of saline taste being derived from this salt, and being the result of sensation, is of course incapable of being defined; we may say, negatively, that the taste is not acid, alkaline, sweet, astringent or metallic.

(c.) *By a red heat, it decrepitates*; e. g. on burning coals, or a red hot iron.‡

(d.) It is essentially anhydrous; does not suffer the aqueous fusion, but melts at ignition, and when cold congeals into a firm mass; by

bleaches as a watery solution of chlorine would do, but, if authors are correct, there is also bleaching power in the chloride of potassa, which is in solution, and the chlorate, according to this view, cannot be formed until the fluid is sufficiently concentrated to produce crystallization, when that salt and the common muriate are produced by the decomposition of water, dividing its elements between different portions of the chlorine which become respectively chloric and muriatic acids.

* Still this substance, except when in the condition of brine, is now removed from the class of salts, and placed with the chlorides; according to received opinions, the parent substance from which all our first notions of saline properties are derived, is not itself a salt.

† Muriate of magnesia is abundant in the bittern of many of the American saline waters; I have found it in several specimens from Ohio; Mr. Chilton discovered muriate of lime and muriate of magnesia, in the salt water of Syracuse, and of other places in the state of N. Y. Sulphate of lime forms a stony crust on the evaporating pans, and in the boilers of the steam engines that are supplied by sea water.

‡ Large firm crystals of West India salt, thrown into an iron pot heated to full ignition by a forge, explode like repeated discharges of small pistols; the fragments fly all around a large room, not without some danger to the eyes, and the surfaces, where they split, are very brilliant, revealing perfectly the structure of the crystals. If the pot is covered with an iron plate, the fragments may be saved for use, but the report is not so loud.

an increased heat, it is volatalized in a white smoke, which condenses in the cold. It loses but 2 or 3 per cent. in weight, and remains nearly unaltered.

(e.) *The air does not change this salt if pure*; but the salt of commerce is usually in a degree deliquescent, owing to the muriates of lime and magnesia.

(f.) *Perhaps this is the only clear example of a salt equally soluble in hot and in cold water.* Strictly, it is soluble at 60° in $2\frac{1}{4}$ water, and at 212° , in $2\frac{1}{3}$; it is usually stated to be soluble in $2\frac{1}{2}$ times its weight of water. It is dissolved more rapidly in boiling water, but no more salt will be taken up in the end.

Therefore, this salt cannot be crystallized by cooling its hot solutions, but only by evaporation, either slow, as by solar heat, or rapid, as by artificial fire. In either case it precipitates, as the evaporation proceeds, forming with solar heat, distinct and firm crystals—with strong artificial heat, a confused mass. Where both are conjoined, as at Syracuse, N. Y. the crystals are regular, but small.

(g.) *With common combustibles, there is no action at any temperature, or under any circumstances*; only potassium decomposes this substance, and liberates half its weight of sodium. In this respect, the muriates (chlorides,) are strongly contrasted with the nitrates, which act with so much energy on combustibles; still chlorine, a powerful supporter of combustion, is believed to exist in these bodies; but it seems that the attraction of combustibles is not sufficient to separate it from the metal. In the arts, salt is often added to increase the intensity of fire; *it appears to act by accumulating and transmitting heat to the combustible bodies in contact with it.* It tinges flame of a yellowish color; this is well seen by burning alcohol in a sponge, with or without salt sprinkled on it; by throwing salt into a hot furnace, or into an active anthracite fire, the flame is increased, probably owing to the extrication of sodium; in the latter case, it is tinged blue.

(h.) The decomposition of this salt by sulphuric acid, to obtain the muriatic, has been already mentioned; *it is decomposed also by nitric acid, and nitro-muriatic acid or aqua regia is formed.* The boric and the phosphoric acids likewise decompose it at a red heat, provided hydrogen or moisture be present, although they do not at all affect it in the cold; this is owing to their great fixity in the fire.

(i.) *Among the alkalis and earths, only potassa and baryta separate muriatic acid from soda, and thus liberate this valuable alkali.**

* It is a great desideratum in the arts, to find an easy and economical method of decomposing the muriate of soda, so as to obtain the soda in a disengaged state. The following is an abstract of some of the leading processes.

Decomposition of muriate of soda for its alkali.

1. By iron; a plate of iron moistened with solution of salt and suspended, gives an efflorescence of carbonate of soda and drops of muriate of iron.

CHLORIDE OF SODIUM.

1. PREPARATION.

- (a.) *By burning sodium in chlorine gas.*
- (b.) *By heating it in muriatic acid gas, hydrogen being evolved.*
- (c.) *By evaporating and crystallizing the solution of muriate of soda, or evaporating it to thorough dryness, without crystallization.*

All the explanations which were given under the chloride of potassium being strictly applicable here, only substituting sodium for potassium, it is not necessary to repeat them.

2. PROPERTIES.—*Absolutely the same that have just been described under the head of muriate of soda.*

If, in the above order, I have violated the received scientific arrangement, it is a sacrifice to convenience, and to common language and common experience.

From common salt we easily obtain muriatic acid by the aid of other acids, and can in no way obtain chlorine, except by supplying oxygen with or from the acids; we easily extract soda, (oxide of sodium,) and can in only one way* procure sodium. The solid chloride can in no way be proved to have any property different from a fluid muriate, and it is therefore highly convenient, if it is not equally scientific, to call it a muriate.† Muriate of soda is now supposed to exist only as a fluid; chloride of sodium only as a solid; thus they are believed to be mutually convertible without limit.

CHLORIDE OF SODA, (chloride of oxide of sodium.)

When chlorine gas is passed into a dilute solution of soda or of its carbonate, a chloride of soda is formed, and all the circumstances that

2. A paste of *quick lime* and strong brine, gives a similar efflorescence, by double exchange; the lime first absorbing carbonic acid from the air, to become a carbonate; but as the muriate of potassa is not decomposed in this manner, the difference is attributed to the efflorescence of the carbonate of soda.

3. Carbonate of lime and brine, (especially if straws or other similar things are standing in the mixture,) give carbonate of soda, by double exchange, as in the natron plains of Egypt.

4. Proposed to line cellars, &c. with a mortar of salt, sand and lime; efflorescence of carbonate of soda often seen on walls made with sea sand.

5. By oxide of lead, 10 parts, salt 5, in solution; grind, let stand 24 hours; the alkali is washed out by water, and the muriate converted into patent yellow by heat.

6. Litharge 7 to 1 salt; the decomposition, after some time and repeated additions of water, is complete.

7. By potassa or its carbonate; 20 lbs. salt, 30 quarts water, 25 lbs. purified pot or pearl ashes; evaporate till 3 or 4 pellicles have formed and been broken; if it stands at 60° it throws down muriate and sulphate of potassa, and finally carbonate of soda appears. For other and numerous particulars see Aikin's Dict. Vol. II, p. 129.

8. Common salt is converted into Glauber's or the sulphate, and the muriatic acid is at the same time, saved; or Glauber's salt, got from any other source, may be used; 1000 lbs. Glauber's salt, 500 lbs. charcoal, 1000 lbs. chalk or lime; heat in a furnace; carbonate of soda effloresces on the surface of the mass, and, in a damp cellar, it falls to pieces, or the carbonate of soda is extracted by solution. This is the process now more generally followed in Great Britain.

* And that one way, by potassium, is equally consistent with the supposition that common salt is a muriate or a chloride.

† It would be difficult to persuade a plain man that the brine in a cask was a totally different thing from the salt on the bottom.

were mentioned in relation to the chloride of potassa are applicable to it; this solution is used in bleaching and in disinfecting.

COMPOSITION OF THE MURIATE AND CHLORIDE.

1. <i>Muriate of soda.</i>		Acid.	Soda.
According to Darcet, contains, in 100 grains,	-	49.27	50.73
Berard, - - - - -	-	43.	57.
Marcet, - - - - -	-	46.	54.
Berzelius, - - - - -	-	46.56	53.44
Average,		46.21	53.79

2. *Chloride of sodium.*

Fused common salt is stated to contain sodium 1 proportion, 24 + 1 of chlorine, 36 = 60, for the equivalent number, and the proportion per cent. is sodium 40.5 + chlorine, 59.5 = 100, or, according to Dr. Wollaston, sodium 39.64 and chlorine 60.36 = 100, and upon the supposition that it is a muriate he admits the proportions of Berzelius. —Henry.

USES OF COMMON SALT.

(a.) *Universally known as the most important antiseptic and condiment, and one of the first necessities of life.*—In curing fish, flesh, butter, &c. its utility is beyond estimation. It enables the most perishable animal substances to endure the heat of the torrid zone, and to remain unchanged for many years. (See the note, Vol. I, p. 473.)

(b.) *Salt is an important article of the Materia Medica.*—It affords muriatic acid, and the residuum of the manufacture is sulphate of soda; carbonate of soda is also obtained from it. Chlorine and chloride of lime, for bleaching, are usually made by means of this salt; it is employed in manufacturing calomel, and in various processes in pharmacy. It is used in glazing coarse earthen ware.

(c.) *Salt is necessary to the health of most animals.*—On the sea coast, the animals either have access to the sea, or their herbage is seasoned by the spray, which the winds transport even a good way into the interior.* It is dispensed as a tonic to domestic, and as a bait to wild animals. In the western parts of the United States, deer, buffaloes, and other wild beasts, crowd to the salt licks, as the saline springs or marshes are significantly called. The remains of the mastodon have been found in the salines, where it is presumed the animal had mired.

Carnivorous animals appear to be exempt from the necessity of using salt; the reason probably is, that the alimentary canal is short, and that their digestion is rapid; salt is said to be even injurious to them.†

* Dr. Robinson says, that "at Glasgow, which is more than twenty miles from the sea coast, after a strong gale from the west, the hedges in winter are very salt to the taste." He adds, "one would imagine that the twigs had been dipped in salt water: one very dry spring I found it crystallized like hoar frost." (Black's Lec. I. p. 465.)

† Vid. Black. I. 456.

ITS NATURAL HISTORY.

The particular description of this salt, as a natural production, belongs to mineralogy; but a few facts may be briefly mentioned here.

1. *In the solid form*, it exists in strata of immense thickness and extent, and is wrought by regular mining. Mines of salt are found in Poland, in England, and Russia, in the Upper Hungary, in Germany, Calabria, Transylvania, Spain, especially in Catalonia, in Italy and other parts of Europe, in the East Indies, &c. Mineral or rock salt is a firm substance, often crystallized in cubes or parallelepipeds; and when translucent and brilliant, *it has been called sal gem*; it is frequently brown, red, grey or yellow, being colored by foreign bodies, especially iron; it has sometimes a fibrous structure.*

Sometimes salt forms hills, and even small mountains. There are two near Astrachan. At Cordova, in Catalonia, there is a hill of salt five hundred feet high, and more than a league in circumference: there are a number in the kingdoms of Tunis and Algiers, in Africa, and several in Asia.†

2. *Salt in solution*.—Every one knows that this salt is found in the ocean, and in lakes and springs: the latter are numerous and rich in the American States, in England, Germany, and in many other countries. The waters of the Dead Sea are a saturated solution‡ of various salts; and the saline springs at Northwich, and at Barton, in England, are also saturated. The ocean contains about 3 per cent. on an average, but it varies in different parts, being of course strongest under the equator.

3. *Extraction*.—It is foreign to the purpose of this work to enter into the details of manufacturing salt. It is sufficient to observe, that it is procured by evaporation, either natural or artificial, and that the salt deposited by natural evaporation is much purer than that obtained by artificial heat. The reason is, that by a rapid evaporation, the deliquescent and bitter salts of lime and magnesia are precipitated along with the sea salt, while by natural evaporation, they remain principally in solution, forming what is called the bittern or mother water, and which is rejected or reserved for other purposes. The salt made in Scotland in this manner is so impure, that it is not fit to preserve beef, fish, or butter; and the salt depos-

* The most remarkable mines of salt in the world are those of Poland and Hungary. (Phil. Trans. No 61 and 413.) That at Williczka, near Cracow in Poland, is supposed to contain salt enough to supply the whole world for many centuries, although it has already been worked for 6 or 7 hundred years. (See Coxe's Travels.) These subterranean regions are excavated into houses, chapels, and other ornamental forms, the roof being supported by decorated pillars of salt. When illuminated by lamps and candles, the scene is one of imposing splendor.

† On or near the coast of Peru, salt forms on the surface of the earth in vast glades, looking like ice, and when removed it forms again. A fine specimen is in the cabinet of Yale College, from Com. Hull, U. S. N.

‡ 44 per cent.; but more than 88 per cent. is muriate of lime and magnesia: a saturated solution of common salt contains 25 per cent.

ited in that country on Sunday, when the workmen are not allowed to add fuel, and the brine remains all day over a slow fire, is more agreeable to the taste, the crystals are larger, and the salt sells for a higher price in the market, where it is known by the name of Sunday salt.*

The same fact is observed at Northwich in England, where the Sunday salt, evaporated over a fire so moderate, that the hand may be held in the solution, is much whiter, and the crystals are larger than ordinary; it is called *shivery salt*.†

In Russia, they concentrate the brine by freezing and removing the ice, which is fresh, and thus, by a process exactly opposite to that of evaporation, the solution grows stronger; but at a very low temperature the muriate of soda and the sulphate of magnesia (which is always present in sea water) exchange principles, producing muriate of magnesia and sulphate of soda; and when the temperature rises, they do not again return to their former state.

MURIATE OF AMMONIA.

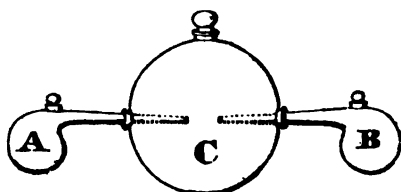
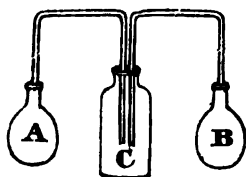
1. NAME AND HISTORY.

Called in the shops *sal ammoniac*, from a sandy district in Lybia,‡ whence, through Egypt, Europe was supplied with it, till about A. D. 1750, when, its nature having been discovered, manufactories were established in different countries of Europe.

It is called hydro-chlorate of ammonia, by those who call the muriatic acid the hydro-chloric.

2. PREPARATION.—*By mingling, in equal volumes, in a glass vessel, the two constituent gases, ammonia and muriatic acid, when the salt is precipitated in snow white clouds, and with considerable heat. This may be done—*

- (a.) By mingling the gases in a jar over mercury.
- (b.) By passing them from flasks with bent tubes, into a dry empty bottle.



(c.) Or, from retorts, into a globe with three orifices, as represented in the figures, Vol. I, p. 385, which are here again inserted.

A, contains sulphuric acid and salt.

B, lime dry slacked, and dry muriate of ammonia; and

C, receives the gases to form the new salt.

* Black. I, 461.

† Watson's Essays, Vol. II, p. 62.

‡ See note, Vol. I, p. 231.

B will need a little heat, and A should not be more than $\frac{1}{2}$ filled with the solid materials.

3. PROPERTIES.

(a.) Sp. gr. 1.42.—*Taste, sharp and bitter ; inodorous.*

(b.) *By heat ; it rises in sublimation, without previous fusion ; its fumes exhaling a peculiar odor. It is not decomposed by passing through ignited glass or porcelain tubes, unless metals are present, when it is resolved into its gaseous elements.*

(c.) *Soluble at 60°, in about 3½ parts of water, and generates 20° or 30° of cold ; soluble in about its own weight of boiling water, and obtained by evaporation in long pyramidal crystals ; primitive form, the octahedron ; integrant particle supposed to be the tetrahedron. Its crystallization is seen beautifully under the solar microscope, shooting in plumose radiations, each filament being a long hexahedral pyramid.*

(d.) *In the air the cakes are little altered, but the crystals are slightly deliquescent. If moistened and laid on litmus paper, it reddens it in a few minutes.*

(e.) *The acids.*—Decomposed by the sulphuric acid, muriatic acid gas being disengaged, and sulphate of ammonia formed. Nitric acid forms with it, nitro-muriatic acid, and nitrate of ammonia.

(f.) *All the alkaline earths, and fixed alkalies decompose this salt, especially with heat, forming a muriate of the base, and liberating ammonia, with its peculiar pungent odor. With the carbonates of these substances, we obtain carbonate of ammonia. By ignition, magnesia also disengages all the ammonia ; but in the cold it decomposes it only in part, and forms a muriate of magnesia and ammonia, for a detailed account of whose properties, see Four. Syst. Vol. III, p. 288.*

We have already seen, that when we decompose muriate of ammonia for its alkali, we always employ lime to attract its acid ; potassa and soda will do it equally well, but they are dearer.

(g.) *When muriate of ammonia is dropped into melted nitre, or the mingled salts are thrown into a red hot crucible, there is a deflagration, arising from the reaction of the oxygen of the nitric acid upon the hydrogen of the ammonia. Doubtless, a similar effect would be produced by the chlorate of potassa.*

4. COMPOSITION.—All the old analyses of this salt presented water as one of its constituents, but this is now considered by most chemists, as adventitious, although it is invariably present in the sal-ammo-

niac of commerce;* according to Berzelius, in the proportion of 19 per cent.

If the salt is regarded as anhydrous, it is very easy to calculate its composition, because it is formed of equal volumes of the two gases, and as 100 cub. inches of muriatic acid gas weigh 39.18 grs. and an equal volume of ammonia 18.18 grs. it follows, that muriate of ammonia is composed of

Acid, 68.519,	}	= {	1 propor. of acid,	37
Alkali, 31.481,			1 " of ammonia,	17 giving

100.

54 for its equivalent

number.—*Henry.*

5. USES.

(a.) *In tinning iron and copper*; these metals are rubbed over with it, or dipped into its solution in order to prevent the oxidation of the metal, and in *soldering metals* it answers a similar purpose.

(b.) *In dyeing*, to fix, brighten and modify the colors.

(c.) *In medicine*, as a diaphoretic, diuretic, discutient, and refrigerant.

(d.) *In chemistry*, to afford pure and carbonated ammonia—to produce cold, and to excite galvanism.

(e.) In some metallurgic and pharmaceutical operations.

(f.) Added to snuff, to give it pungency.—*Gray.*

6. ORIGIN AND MANUFACTURE.

(a.) Found in small quantity, occasionally sublimed, in volcanic countries, as at Solfaterra, in the caverns and crevices; or adhering in tufts to volcanic stones.

(b.) Dissolved in small quantities in the waters of the Tuscan lakes, and in sea water; it may be sublimed from the bitter.†

(c.) In the clefts of the ground or of rocks in the vicinity of coal mines that have been long burning.‡

(d.) In some vegetable juices, and in animal substances, especially after putrefaction.§

(e.) *In Egypt, it is made from the dried excrements of ruminating animals, which form their principal fuel.*—The animals feed largely on saline plants, and probably thus obtain the muriatic acid to form the salt

* Much importance was attached by the late Dr. Murray of Edinburgh, to the existence of water in muriate of ammonia, formed from the dry gases, because it went to prove the existence of water in muriatic acid, a fact of great interest in the discussion respecting the nature of chlorine. See the appendix to Murray's Elements of Chemistry, edited by his son, Edinb. 1828, which exhibits a luminous and interesting view of this controversy.

† Marcet, in Phil. Trans. 1822, p. 454.

‡ Black, I, 469.

§ Four. III, 274.

with the ammonia of the animal matters. The ashes or soot of this fuel, placed in glass vessels, 18 or 19 inches in diameter, is heated without addition; the salt begins to sublime on the second day, and on the third, is found adhering to the roof of the glass vessel which is broken to extract it. Five pounds of soot yield one of the salt.

(f.) *The soot of pit coal containing sulphate of ammonia, is lixiviated; to decompose it, lime is added, and a weak but tolerably pure liquid ammonia is obtained by distillation. Sulphate of ammonia being again formed by adding the sulphuric acid, is sublimed in glass vessels, in mixture with muriate of soda, and by double decomposition, we obtain muriate of ammonia above, and sulphate of soda below.*

(g.) *In the distillation of mineral coal for gas lights, an ammoniacal liquid is obtained, which is turned into sulphate of ammonia and then, as above, into muriate. The salt is manufactured, in this mode, in England. On the continent, they follow processes somewhat different.*

(h.) *A carbonate of ammonia is formed by the distillation of animal substances.—With this they combine the muriatic acid.*

1. *By mixing with the ammoniacal liquid, the muriate of lime, which remains in the mother water of the salt pits, and after evaporating to dryness, they sublime the muriate of ammonia in glass vessels.*

2. *In a capacious leaden receiver, or in leaden chambers, they combine the muriatic acid gas, disengaged by the sulphuric acid from muriate of soda, with the ammonia, obtained from the distillation of animal substances.**

3. *A sulphate of ammonia is formed, by mixing the liquid carbonate of ammonia just mentioned, with sulphate of lime, and the alkaline sulphate, after being obtained concrete by evaporation, is heated in proper vessels with the muriate of soda.*

The impure salt obtained in all these ways, answers for some purposes in the arts, but for greater purity, it must be sublimed again, or obtained in crystals by solution.

MURIATE OF BARYTA.

1. PREPARATION.

(a.) *Carbonate of baryta decomposed by muriatic acid, diluted with 3 parts of water, is evaporated till the solution will crystallize.*

(b.) *As the carbonate of baryta is rare, and the sulphate abundant, the muriate is generally prepared from the sulphate, previously decomposed by ignition with carbon, as already stated under the carbonate of baryta. The warm solution of the hydro-sulphuret, thus obtained, is decomposed by muriatic acid and the solution, by evaporation, affords crystals.*

* See Gray's Operative chemist.

(c.) Or, it is a neater method to *decompose the hydro-sulphuret by a carbonate of an alkali, and then to decompose the washed carbonate by muriatic acid.* If the crystals contain iron; calcination, by oxygenating the iron, will render it insoluble, and the pure muriate may be again dissolved in water, and then evaporated and crystallized anew. Or, the iron and even the lead which is occasionally dissolved, may be precipitated by ammonia, or by boiling and agitating with lime, or better by barytic water.

2. PROPERTIES.

(a.) *The primitive form of the crystals is a rectangular prism with square bases; most usually crystallized in tables, but sometimes in the form of two eight sided pyramids, applied base to base.*

(b.) Sp. gr. 2.82. *Soluble in $2\frac{1}{2}$ or 3 parts of water, at 60° , and still more so in boiling water. It is also soluble in diluted, but not in pure alcohol.*

(c.) *Taste acrid and pungent, and sub-metallic.*

(d.) *Air has no effect upon it.*

(e.) *By heat, decrepitates and falls to powder; with a high heat, it melts, but no heat decomposes it.*

(f.) *Among acids, the nitric, fluoric and sulphuric alone decompose this salt.*

(g.) *It is the best test of the sulphuric acid in solution, for there is a very visible precipitate, when the acid amounts only to $\frac{1}{100}$, and a slight cloud appears in a few minutes, when the proportion is only $\frac{1}{1000}$.**

It also decomposes all the soluble sulphates, and thus detects the combined sulphuric acid, in an immense volume of water.†—Four. III, 236.

(h.) *No base decomposes this salt, but the alkaline bases when united even with weak acids, effect its decomposition by double exchange. On the other hand, baryta decomposes all the salts, and were it cheap and abundant, it would be of great use in the arts.*

3. USES.

(a.) *As a test for sulphuric acid.*

(b.) *In medicine, particularly in cases of scrofula—tumors, worms, and cutaneous affections; but the faculty are divided in opinion respecting its utility. As it is a poison to warm blooded animals, the solution of 1 part of the crystals in three of distilled water, is cautiously given, in doses of from 5 to 10 drops—twice or thrice in one day, but the dose must be diminished when it produces nausea and*

* Bergman, I, 100.

† In a very concentrated solution of this salt, the nitric acid also forms a precipitate, because the nitrate is one half less soluble than the muriate.—*Id.*

giddiness. Mr. Watt poisoned dogs with half a drachm. It has been used in veterinary practice, but with doubtful advantage.

CHLORIDE OF BARIUM.

1. PROCESS.

(a.) *By heating pure baryta to ignition in chlorine gas*, which expels half its volume of oxygen gas, and takes its place to form a chloride; or by the old theory, oxy-muriatic acid is decomposed; its oxygen is evolved, and its muriatic acid combines with the baryta to form a dry muriate.

(b.) *By heating baryta in muriatic acid gas*, the gas is decomposed and the resulting chloride becomes ignited.

(c.) *By igniting the crystals of the muriate*, the hydrogen of the muriatic acid unites with the oxygen of the baryta, (oxide of barium) to form water, which is expelled in vapor, and the chlorine unites with the barium to form chloride of that metal. By the old theory, the water would be derived from the muriatic acid gas, and the resulting compound would be a dry muriate. A similar explanation would be given under (b.)

(d.) *This substance is supposed to exist always in the state of muriate*, not only when in solution, but also when crystallized; and its crystallization, from the state of aqueous solution, is not supposed to convert it into a chloride, as in the cases of potassa and soda, although no reason appears for the exception which is admitted in this and in several other cases.*

2. *THE PROPERTIES of the chloride of barium appear to be the same with those of the muriate*, and by solution, the chloride is believed to pass instantly into the state of a true muriate, so that the chloride, it is supposed, cannot exist in solution, but the muriate may be in both forms.

3. COMPOSITION.—*The chloride consists of chlorine 34, and barium 66=100, or, of 1 proportion of chlorine 36, + one of barium, 70=106, its equivalent number.*

(a.) *The muriate, formed by dissolving the chloride, is supposed to decompose 1 equivalent of water for each equivalent of chloride, and thus $36 + 1 = 37$ muriatic acid, and $70 + 8 = 78$ baryta, =115 the equivalent of the muriate, supposing it to be anhydrous; and per cent. the proportions will be 32.17 acid, + 67.83 base, =100. But by ignition, the crystals lose, in weight, 18 out of 124, of which, as it passes to the condition of chloride, the hydrogen of the acid is 1, and the oxygen of the baryta is $8 = 9$, which leaves $9 = 1$ proportion of water in the crystals; this gives the composition of the crystallized muriate as follows;*

* Unless it be from the water of crystallization.

CHLORIDE OF MAGNESIA.

1. PREPARATION.

(a.) *By saturating with chlorine gas, magnesia suspended in water.*

(b.) *By double exchange between chloride of lime and sulphate of magnesia, forming sulphate of lime and chloride of magnesia.*

It is used in bleaching and in calico printing, but has not been examined with precision.

The chloride of magnesium can be formed by heating magnesia in chlorine gas ; it is however scarcely known ; it cannot be produced by igniting the muriate, as the latter is decomposed by heat.

PROCESS FOR OBTAINING MAGNESIA.

The muriate of magnesia in the bittern waters, may be easily distinguished from the muriate of lime. Sulphuric acid which disengages muriatic acid gas with effervescence from both, forms no precipitate with magnesia, because the sulphate of that earth is very soluble ; but it precipitates the lime from muriate of lime, forming with it sulphate of lime ; or, both earths may be precipitated from the bittern by carbonate of soda or ammonia, heating the liquor to insure the entire precipitation, and then sulphuric acid will form with the magnesia, a very soluble, and with the lime, a nearly insoluble sulphate, most of which will remain as a white precipitate.

To procure magnesia in the arts, *the bittern of sea water is decomposed, by a crude carbonate of ammonia*, obtained from the distillation of bones in iron cylinders. Carbonate of magnesia is precipitated, and the muriate of ammonia, after being evaporated to dryness, is turned again into carbonate by being sublimed with chalk, and with this, more bittern is decomposed, and so on without limit, giving a useful and cheap process.

The bittern* is also poured upon magnesian limestone, and its acid, dissolving the lime, liberates both its own magnesia and that of the limestone : if sulphuric acid is added, it turns it into sulphate of magnesia. Carbonate of potassa is sometimes employed to decompose the muriate of magnesia.

MURIATE OF LIME.

Remarks.—Muriate of lime exists in the mother water of salt-petre ; in many mineral springs,† and in wells, particularly, as is said, in those of the city of Paris.

* As much magnesian limestone is mixed with the bittern as corresponds to an equal weight of solid matter found by evaporation to be contained in the bittern.

† Constituting, according to Dr. Murray, their most common and active ingredient.

1. PREPARATION.

(a.) *Obtained cheapest, by the decomposition of sal ammoniac by lime, in the manufacture of ammonia.*

(b.) *By dissolving lime or carbonate of lime, to saturation, in muriatic acid, and evaporating the solution to the consistence of a syrup, when it will crystallize.* But, if it retains its water of crystallization and is perfectly dry, it is then most effectual in generating cold, and it will serve as often as it is crystallized anew.*

By means of this salt and snow, quicksilver is easily frozen.

2. PROPERTIES.

(a.) *Taste bitter; sp. gr. 1.76.*

(b.) *The crystals† are six sided striated prisms, terminated by acute pyramids; sometimes acicular.*

(c.) *By heat, melts, dries, loses a little acid and its water of crystallization and becomes a sub-muriate. In this state it is phosphorescent, and was called the phosphorus of Homberg, after the discoverer of this property.*

(d.) *Very deliquescent, speedily becoming fluid in the air, and is therefore kept in close vessels.‡ On account of its strong attraction for water, it is employed to dry the gases and to generate cold, by mixture with snow.§*

(e.) *Soluble in half its weight of cold water, and in still less if boiling. When of the sp. gr. 1.45 at 80° Fahr., the solution crystallizes at 32°, and is fit for experiments at that temperature, but if to be used at any temperature, the sp. gr. should be as high as 1.49 at 80°.*

The strong solution sometimes remains fluid in the cold, but becomes suddenly solid and very hot by the least agitation.

(f.) *Sulphuric acid expels the muriatic acid gas, and if the solution is strong, the sulphate of lime is precipitated so dense, that the glass may be inverted without dropping any thing. The nitric acid forms nitrate of lime and nitro-muriatic acid.*

(g.) *The alkalis and alkaline earths decompose this salt, forming muriates and precipitating the lime; still the muriates of soda and*

* It may be heated till it becomes a dry powder, but it is most convenient to evaporate the solution, to the consistence of a syrup, (or sp. gr. about 1.45); if it be then stirred while cooling, it will be broken down into parts of convenient size, for forming a freezing mixture.—*Dr. Hope.*

† According to Dr. Thomson, (*First Prin.* Vol. I, p. 277,) the muriate of lime is easily crystallized, by placing a concentrated solution of it under the exhausted receiver of an air pump, over a flat glass vessel containing strong sulphuric acid.

‡ I have known it, when put up in the state of dry powder, to keep unchanged for twenty years.

§ See *Nich. Jour.* 4to. V, 222, for many curious particulars concerning freezing mixtures.

potassa are, in turn, decomposed by lime, and, in the atmosphere, muriate of lime and carbonate of soda are the result.

(h.) *When saturated solutions of muriate of lime and of carbonate of potassa are mixed, a solid mass is precipitated.*

(i.) *Not decomposed by pure ammonia, but readily by the carbonate, producing muriate of ammonia and carbonate of lime.*

CHLORIDE OF CALCIUM.

1. PREPARATION.

(a.) *By heating lime in chlorine gas; for each volume of chlorine absorbed, half a volume of oxygen is expelled.*

(b.) *By analogy, we should expect the same compound to be formed by heating lime in muriatic acid gas.*

(c.) *By fusing the muriate of lime, formed as already described; the same change is supposed to happen that has been mentioned in similar cases; the hydrogen of the muriatic acid uniting with the oxygen of the earth, to form water, and the chlorine remaining in union with the calcium, to form chloride of calcium; and the same explanation would be given under (b.); by the old theory, it would be merely the formation of a dry muriate, water being expelled by the heat.*

2. PROPERTIES.

(a.) *The chloride, obtained in all these cases, becomes again a muriate, by solution in water, whose elements regenerate the acid, and the earth; and again the muriate, by igneous fusion, becomes a chloride; thus they are considered as being mutually convertible.*

(b.) *The dry crystals being regarded as a true muriate equally with the solution, we are unable to point out any important distinction of properties; nor does the fused muriate, which has thus become a chloride, present any difference, except a greater avidity for water, which results of course, from the expulsion of that fluid by heat.*

(c.) *There is therefore, no such thing as a dissolved chloride of calcium; nor a fused* muriate of lime; neither will the latter be permanent in its new state of chloride, for as soon as it has deliquesced, it becomes again a muriate, and deposits crystals at 32° Fahr.*

3. COMPOSITION.

(a.) *Of chloride of calcium.*—Berzelius calculates that 100 grs. of carbonate of lime afford 109.6 of fused chloride of lime, containing, by calculation, 69.6 chlorine, and 40. metal, which corresponds, almost exactly, with the equivalent number of chlorine, 36, and that of calcium, 20=56, the equivalent of chloride of calcium. In the 100 parts, chloride of calcium, will therefore be composed of chlorine 64 + calcium 36=100.—*H.*

* The true fusion of the saline particles is intended; not the mere aqueous fusion.

(b.) *Of muriate of lime.*—Dr. Thomson states* the composition of this salt as being—

Acid,	1	proportion	37	} per cent. {	31.09
Lime,	1	"	28		23.53
Water,	6	"	54		45.38

Making for its equiv.	119	100.00
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By ignition, 119 parts of the salt lose 63, which consists of the 6 proportions of water 54, + 9 = 1 equiv. of water more, formed by the oxygen of the lime, and the hydrogen of the acid.

4. USES OF MURIATE OF LIME.

(a.) *Affords with snow, the most powerful means of producing cold*, except perhaps crystallized potassa.

(b.) *It is used in medicine* as a deobstruent, and according to Fourcroy, it is an active solvent of lymphatic swellings, and an useful remedy in scrofulous affections. It is used also to concentrate alcohol by attracting water.

(c.) *Medical preparation.*—Marble powder 9 oz., muriatic acid 16, water 8, dissolve, evaporate to dryness, and redissolve in 1½ times its weight of water. Dose, 36 drops for children, and a drachm for adults, twice or thrice a day.

CHLORIDE OF LIME.

1. PREPARATION.

(a.) *In the humid way.*—*Slacked lime* is diffused in water, and kept suspended by mechanical agitation, while *chlorine gas* is passed through it, to saturation.†

(b.) *In the dry way*, this chloride is manufactured on a great scale in stone chambers,‡ by Mr. Tenant at Glasgow; and at Baltimore§ in this country. In the latter case, a large chamber lined with lead is used, and about 5000 lbs. of hydrate of lime being placed thinly on moveable shelves, the chlorine gas is then introduced into the chamber, and is absorbed by the lime: the top shelves are saturated first, the lime is then stirred, and the shelves reversed, those at the top being placed at the bottom, and those on the bottom at the top, and so on through the whole, introducing additional quantities of chlorine as the shelves are transposed, and the gas is absorbed.|| It is made also in New York, and in Philadelphia.

* First Principles, Vol. I, p. 277.

† This process was formerly patented, (1798,) by Mr. Tenant, in Scotland, but the patent was broken in a trial at law, and now the chloride is prepared for the arts in the dry way.

‡ Rooms of sandstone are now preferred in G. Britain.

§ For an elaborate account of the bleaching powder, its manufacture and use, see Ure's Dict. 2d Ed. p. 574.

|| G. W. Carpenter, Am. Jour. Vol. XVI, p. 177.

2. PROPERTIES.

(a.) Mr. Dalton,* Dr. Thomson,† and Mr. Welter,‡ conclude, that the bleaching powder is a compound of 1 proportion of chlorine 36, with 2 of lime 56, and they therefore call it a sub- or di-chloride; and they suppose that when this substance is dissolved in water, it is the real chloride that is dissolved, and that 1 proportion of lime is separated.

Dr. Ure denies that it is a definite compound, and says that he could never observe this separation.

(b.) *Dry chloride of lime has a faint odor of chlorine, and, by exposure to the atmosphere, is gradually decomposed*, especially when in solution, chlorine being liberated, and carbonate of lime being formed; by boiling—heat decomposes the chloride, and if carried as high as 600° Fahr. it evolves chlorine and oxygen gas, and sometimes euchlorine, and leaves chloride of calcium, or dry muriate of lime.

(c.) *The chlorine nearly neutralizes the lime*, destroying in a great measure its alkaline properties.

(d.) *Decomposed by acids, even by the carbonic, with evolution of chlorine gas.*

(e.) *Aqueous solution of the chloride, is decomposed by boiling*; by the decomposition of water, muriatic acid is rapidly formed, oxygen gas being evolved, and its bleaching power is thus destroyed.§

3. USES.

(A.) BLEACHING BY CHLORIDE OF LIME.

(a.) It has already been mentioned under the history of *chlorine*, that this agent is *very powerful in destroying color*, especially in vegetable bodies. Both the gas and the watery solution were early (1784–5,) employed in bleaching, but the effluvia were so suffocating that they could not be borne by the workmen. Afterwards, (1789–90,) the gas was condensed in a solution of pearl-ashes, and used in France under the name of *the ley or liquor of Javelle*. In 1798, Mr. Tenant employed lime diffused in water to condense the gas, and now the dry chloride is dissolved for that purpose.

(b.) *The strength of the bleaching powder is determined by its action on indigo*,¶ 2 grains of which are bleached by 1 of the chloride of lime. The quantity of gas extricated from it by muriatic acid, or even by vinegar, affords also a good criterion of its strength. To dissolve out dirt, grease, and resinous matter, *the stuffs chiefly linen and cotton, are steeped in hot water, or in waste cold alkaline leys; they are then boiled in a caustic alkaline liquor, so dilute as*

* Ann. Phil. Vol. I.—II.

† Ib. Vol. XV.

‡ Ann. de Chim. et de Phys. Vol. VIII.

§ Am. Jour. Vol. XV, p. 392.

¶ For a very full, interesting, and instructive article on bleaching, see Parkes' Essays, Vol. II.

¶ This test is not very precise, as the quality of indigo varies very much; muriate of manganese appears to be far preferable.—Am. Jour. Vol. XVII, p. 170.

not to injure the fibre ; and this steeping in hot water, and boiling in caustic alkali are repeated several times, more or less frequently, according to the nature of the material ; linen being much more difficult to bleach than cotton, and generally requiring three or four *buckings*, as the immersion in the caustic ley is called, before the chloride of lime is applied. *The goods are next immersed in a solution of the chloride of lime.* They are then again washed in water, and exposed to the action of very dilute sulphuric acid ; they are now again washed in water, and exposed anew to the alkali, and then again washed, and replaced in the solution of the chloride, and in this way *there are several alternations in the use of these different fluids, and weak sulphuric acid is again applied, which gives them a beautiful whiteness.* Lastly, *they are cleansed by being boiled in a dilute solution of pearl ashes and white soap,* which removes any odor of chlorine, and any remains of acid.

(c.) *Sometimes the chlorides of potassa and soda and even of magnesia and alumina are preferred to the chloride of lime,* especially in bleaching cotton for calicoes ; because the sulphuric acid used to cleanse the stuffs forms with the lime an insoluble sulphate, which adheres obstinately to the fibres of the cloth, and being a mordant, particularly for madder, it stains those parts that were intended to be white, whereas the bases of the other chlorides,* form with sulphuric acid a compound completely soluble, which is removed by washing.

(d.) **ADVANTAGE OF THE NEW BLEACHING PROCESS.**—*Principally in time ; it is more than the difference between weeks and months : a few days are now sufficient for small quantities, and a few weeks for the largest.* The process is also *independent of the weather and seasons, and has restored the large bleach fields to agriculture.* The materials of the new process are as much dearer as the cost of the chloride of lime, but the interest of capital is, on the whole, much less, and the process is certain, and does not injure the goods.

(e.) *Theory of the process.*—*In bleaching by the old process, (still extensively practiced in this country,) oxygen is absorbed from the air, and renders the coloring matter soluble in alkalies, the immersion in which removes the exterior film, and thus to the eye, the color is renewed, and appears as if going back to its first stage, but this is merely because a new portion of coloring matter is disclosed, by the removal of the substance that covered it ; a new exposure to the bleaching agent renders a new film soluble, which a new immersion in the alkali removes, and so on until the whole is discharged.*

(f.) *In the new process, the oxygen of the water performs the office of the oxygen of the air in the old ; and in every other respect*

* The chlorides of magnesia and alumina have sometimes also been preferred because the muriates of their bases do not injure the fibre.

the operation and theory are coincident. *The chlorine appears to act in bleaching, by decomposing water, whose hydrogen goes to form muriatic acid, which is always found when liquid chlorine is used, and a muriate when a chloride is employed. It also decomposes the coloring matter, one of whose elements is always hydrogen, and its composition being thus subverted, it is rendered soluble and removed.** By the former theory, the oxygen of the oxy-muriatic acid acts on the coloring matter, and muriatic acid, or a muriate is left; in the other steps the two theories are coincident.

The new bleaching process was a great present from chemistry to the arts.

(B.) POWERS OF CHLORINE IN DISINFECTING AND CURING.

(a.) *Chlorine is by far the most powerful agent hitherto discovered to counteract contagion, and all kinds of noxious effluvia, and its sanative powers appear equally extraordinary.* The chloride of lime† is generally used for these purposes, and is employed in solution, four ounces to one pint of water. Dilute one part of the liquid with 40 of water, a pint with five gallons, or a wine glass full with three quarts of water; stir the mixture and it is then fit for use. It instantaneously destroys all bad effluvia, particularly those arising from animal, and vegetable decomposition, and effectually prevents their deleterious influence; hence, in epidemic districts, the mixture sprinkled about apartments will probably prevent the access of contagion, to a certain extent around. In examinations for inquests and in anatomical rooms, it is necessary only to sprinkle the diluted liquid in the apartment, or on the object requiring purification.

The effluvia from drains, sewers, &c. will be destroyed by pouring into them a quart of the mixture, added to a pailful of water, and repeating the operation until the odor is completely removed.

Tainted meat is rendered inodorous. Water in cisterns is purified, and animalculæ are destroyed, by a pint of the solution to one hundred and twenty gallons of water; and on ship board it counteracts the effluvia arising from bilge water, and from wounds, and confined air.

It destroys the smell of paints, and a room painted in the day, may be slept in at night, if sprinkled some hours before with the mixture.

* Bleaching, particularly of cotton, is now performed by high steam without the aid of chlorine. The goods are exposed alternately to an alkaline lixivium, and to the vapor arising from it at 220° or 230° which renders the resinous and other coloring matter of the cloth soluble in alkali.—*Parkes*.

This process is also applied to the whitening of rags for the manufacture of paper, and lime is sometimes substituted for the alkali.

† First employed by Mr. Massouger about 1809, in the military hospital at Strasbourg; he used the solution, and this is found to be gradually decomposed by the carbonic acid produced by putrefaction, and thus the chlorine is so gradually liberated, that it produces no annoyance: if a more prompt effect is desired, a stronger acid added to the chloride, will evolve the chlorine instantly and abundantly. The chloride of soda undergoes decomposition in a similar way, only more slowly.

The nuisances arising from disagreeable and unhealthy manufactories* may be equally obviated by the mere sprinkling of the chloride of lime, and the health of the workmen preserved.

Smelters of lead, and makers of glue, tallow and soap manufacturers, skin dressers, &c. may deprive their premises of all offensive smell, by the same processes, and the close and confined air of hospitals and prisons is purified by sprinkling the diluted chloride of lime in small quantities from a watering pot.

(b.) *The chloride of soda has lately been most beneficially introduced into the materia medica.* The chlorides arrest animal and vegetable decomposition. Chlorine acts chemically upon the morbid matter, and resolves it into innocuous principles; the application of the chloride of soda in carbuncle, ulcers, gangrenous sores, and mortification, and in cutaneous diseases has been successful.†

The proportions to be used vary with the disease; externally, the weak solutions, frequently repeated, are more effectual than the stronger mixtures. The use must be suspended when the sores are red and inflamed. In this country it has been most successfully used in all the foregoing cases. Diseases of animals of a similar nature will be cured by the same means.‡

It cleanses the teeth and gums, and it is used as a gargle in the ulcerated sore throat. Physicians, and persons engaged about the beds of people sick with contagious diseases, should moisten their hands and nostrils with a dilute solution of chloride of lime, or a solution of chlorine.

Chloride of lime is powerful in restoring persons suffocated by bad gases, especially sulphuretted hydrogen.§

(c.) *Chlorine gas is sometimes employed in fumigations where an active effect is desired,* but the apartments must be previously emptied.

Mr. Faraday fumigated the general penitentiary at Millbank, England, by seven hundred pounds common salt, seven hundred manga-

* In a manufactory in Scotland where the bleaching materials of the new process are employed, the solid residuum of the distilling vessels is heated in the cottages infected with fever, the family being removed and the house closed, and for twenty years no fever had made any progress in that establishment.—Parkes' Essays, Vol. II. p. 345.

† Both chlorine and chloride of lime have, it is said, prevented or cured hydrophobia.—Am. Jour. Vol. XVII, p. 204.

‡ Carpenter in Am. Jour. Vol. XVI, and M. Labarraque's pamphlet, translated by Dr. Porter; see also Dr. Beck, in Am. Jour. Vol. XIV, p. 241, and Gay-Lussac on chlorometry, Jour. de Chim. et de Phys.

§ Chlorine has been administered in Paris as a remedy in Phthisis pulmonalis, and a complete cure in one case of a student of medicine, was reported to the Academy in August, 1829, by Magendie and Dumeril. Dr. Cotterau has contrived an apparatus, with which, by a small lamp and thermometer, the patient is enabled to separate the gas from an aqueous solution of chlorine at a given temperature, so cautiously that the drops of the solution may be counted, and the tube through which the chlorine is breathed, shut so as not to lose an atom.—Report of the Institute for August.—J. G.

nese, and fourteen hundred oil of vitriol, and thus purified a space of 2,000,000 cubic feet; he thinks that a smaller quantity of the materials would have answered; the gas continued to be exhaled for four days.*

POLARITY OF CHLORINE.—Like oxygen, it is attracted to the positive pole.

MURIATE OF ALUMINA.

Newly precipitated alumina is dissolved in muriatic acid; it does not crystallize; it forms a gelatinous and acidulous mass; deliquescent; astrigent; very soluble; loses its acid by heat and leaves the earth.

The muriates, chlorates and chlorides of the other earths, have been little investigated, or are, as far as known, possessed of no peculiar properties.

Remarks.—It is worthy of observation that *the dry muriates and chlorides cannot be decomposed by dry vitreous acids* and acidulous salts, such as boracic and phosphoric acids and super or bi-phosphate of lime; but if water, or any thing that will afford it or its elements, be present, then the muriatic acid gas is abundantly obtained.

Upon the new view, it is supposed that the substances in question being chlorides, water is necessary to act by its elements to give oxygen to the base and hydrogen to the chlorine, so that the former may combine with the acid to form a salt and the latter may become muriatic acid gas and escape in that condition.

Upon the old view, the water was thought to be necessary to the separate existence of muriatic acid; the combined acid being supposed anhydrous, and the acid gas being incapable of aerial existence, without acquiring one fourth of its weight of water.

Those who feel interested in the curious but rather complicated, and yet interesting discussion, relative to the old and the new views of the nature of chlorine and its combinations, will find a luminous account of the subject in the appendix to the 6th ed. of the Elements of Murray's Chemistry, Edinb. 1828, which has been already cited.

The least satisfactory part of the present chlorine theory is the easy transmutation of muriates into chlorides, and of chlorides into muriates; also, of the chlorides of the oxides of metallic bases into chlorates and muriates of those bases, and of chlorates into muriates of oxides of bases and metallic chlorides of those bases. Among these instances, nothing appears more extraordinary, than that the solution of muriate of soda, consisting of chlorine and hydrogen for the acid, and of sodium and oxygen for the alkali, should, by the mere act of crystallization, give up the oxygen from a combination of the most energetic kind, namely, with the sodium;† and hydrogen

* Ure, and Eng. Jour. of Science, Vol. XVIII. p. 92.

† Which no single affinity but that of potassium will overcome.

from a combination not dissimilar, (for chlorine either singly or by double action takes hydrogen from every thing,) and thus form water, to add a little to the mass of the fluid in which the process is going on; while the chlorine and sodium form a chloride, which remains unaltered, although lying in the water, which is its birth place: still, the mere solution of this chloride is sufficient again to disjoin the elements of the water and to cause them to form, anew, the muriate of soda; and so, back and forward, as often as crystallization and solution take place, this interchange of the elements is renewed, but with no appreciable difference of properties, between substances so remarkably different in constitution, as muriate of soda and chloride of sodium. May we not suspect that there is something yet to be discovered respecting this subject?*

The new view, although decidedly preferable to the old, is not without its dark points. If the subject has ceased to be regarded as a *lis pendens*, still it may be best to keep the former opinions in remembrance, at least as being a curious part of the history of the science, even if they are no longer important in its elucidation.

NITRO-MURIATIC ACID.

1. PROCESS.—*Formed by mixing 2 parts, by weight, of nitric with 1 of muriatic acid; or the reverse; or equal proportions; or 1 nitric and 4 muriatic; authors recommend all these and other proportions. Equal measures give an active acid for dissolving gold.*

2. PROPERTIES.

(a.) *Deep red color*; if the acids are strong, there is an effervescence spontaneous and active, with the mixed odor of chlorine and nitric oxide gas, or rather nitrous acid vapor, which are, by heat, obtained in mixture, and by a long continued heat these gases are entirely expelled, and there remains a mere mixture of nitrous and muriatic acids, incapable of dissolving gold.

(b.) *It dissolves gold*; (rex metallorum, thence the name, aqua regia;) if combined with alkalies or with earths, it forms merely mixed nitrates and muriates or chlorides, and nitrous gas is evolved.

(c.) In its action on metals it *yields muriates or chlorides only.*

(d.) It is *formed in various proportions* for different purposes, and *appears to be mainly a mixture of chlorine and nitrous and muriatic acids.* The nitric acid is supposed to afford oxygen to the hydrogen of the muriatic acid, thus forming water and evolving chlorine and nitrous acid. Upon the old theory the nitric acid was supposed to impart oxygen to the muriatic, thus generating nitrous acid,† and liberating muriatic acid.

* Berzelius maintains that the soluble chlorides dissolve, as such, without changing into muriates.—J. T.

† Sir H. Davy (English Journal of Science, No. I, p. 67,) says, that if strong nitrous acid, saturated with nitrous gas, be mixed with strong muriatic acid, the latter

IODINE, (from *Iodēs*, violaceous.)

1. **DISCOVERY AND HISTORY.**—*In 1811 or 12, at Paris, by M. Courtois, a saltpetre manufacturer.** This gentleman, in preparing the barilla or carbonate of soda, from the ashes of marine plants, (*cendres de varech*), found that the remaining fluid powerfully corroded the iron vessels in which it was contained. Sulphuric acid precipitated a dark colored substance, which by heat became a beautiful violet vapor. Being examined by Clement and Desormes, it was found to be a new principle, whose properties have been since fully investigated by some of the ablest chemists of the age.†

2. **PREPARATION.**

(a.) *Obtained chiefly from the liquor remaining after the crystallization of soda from the lixivium of the ashes of marine plants.*

(b.) *Evaporate this fluid until most of the soda and common salt have crystallized out; add a little diluted sulphuric acid to precipitate sulphur and to disengage muriatic acid, and then evaporate to dryness; this saline mass will contain the iodine, if any were present in the materials.*

(c.) *To this mass, contained in a tubulated retort, furnished with a tubulated receiver, add half its weight of strong sulphuric acid; there will be a brisk effervescence and a violet colored vapor will fill the vessels, which will be increased by heat and will condense into a dark colored solid, in the neck of the retort and in the receiver.*

It is found useful to add about one sixth part of manganese, which prevents the decomposition of the sulphuric acid and the formation of sulphurous acid, which acts upon the iodic vapor.

(d.) *Dr. Ure‡ found that iodine can be advantageously extracted from the brown oily looking liquid which forms the waste lye of the soda soap boilers, in Scotland. This liquid, (sp. gr. 1.374,) being saturated at 230° F. with diluted sulphuric acid, of which it requires 1 ounce measure to 8 of the fluid, is then cooled to separate the crystals of sulphate of soda and sulphate of potassa, and also some*

produces no other effect than so much water, and the mixed fluid will not dissolve gold. I can only say that this is contrary to my experience; I have constantly found a very active aqua regia produced by the strongest red fuming nitrous acid mixed with the strongest muriatic, dissolving gold with energy, and when the action has ceased, which is the fact eventually, especially if heat is employed, it is renewed by the addition of a drop of alcohol, which produces more nitric oxide gas, and of course, nitrous acid.

* The discovery was published in 1813.

† Vauquelin, *Ann. de Chim.* Tom. XC, p. 206. Gay-Lussac, *ibid.* XCI. Claubry and Colin, *ibid.* XC, XCI, XCIII. Davy, *Phil. Trans.* 1814-15: also *Ann. de Ch.* Tom. LXXXVIII.

‡ *Chem. Dict.* art. Iodine.

sulphur; it is next filtered and mixed when cold with about one sixth of black oxide of manganese; and lastly it is heated in a glass vessel and the iodine copiously sublimes.*

3. PROPERTIES.

(a.) *A soft solid at common temperatures, friable, easily crushed between the fingers, giving them a dull brownish yellow stain, gradually disappearing as the iodine evaporates.*

(b.) *Color, bluish black with a metallic lustre, but as it appears in the shops, rather dull, like plumbago.*

(c.) *Sometimes in brilliant rhomboidal plates or scales, like the oligiste or micaceous iron; or in regular crystals, often acute octahedra, which is the primitive form.*

(d.) *Odor pungent and disagreeable, resembling that of chlorine mixed with air—taste acrid.*

(e.) *Sp. gr. at 60°, 4.946, but according to Dr. Thomson, only 3.0844.†*

(f.) *A non-conductor of electricity; if a small fragment of it be placed in the voltaic chain, it instantly interrupts the decomposition of water; and in the GALVANIC CIRCUIT, IT GOES TO THE POSITIVE POLE like chlorine, oxygen, and bromine,‡ the only other elementary bodies that are electro-negative.*

(g.) *In water, almost insoluble; requiring 7000 parts to dissolve one.*

(h.) *Evaporates spontaneously, at common temperatures, and, if left in the air, it gradually vanishes, notwithstanding its density; it is constantly exhaling its peculiar odor, and if the eye be favorably situated, a violet vapor may be seen rising from it. It melts at 225°, and boils at 347° Fahr. or at about 350°, under the common atmospheric pressure.*

(i.) *Its vapor, raised by heat, is of a splendid violet, whence its name; it is best exhibited by placing some of the solid substance in a large glass retort or flask, and warming it gradually over a few coals; the mouth of the vessel should be but loosely stopped, and it ought to be, as far as possible, heated equally; the vapor is best seen by transmitted light, and nothing can exceed it in beauty. It con-*

* In evaporating the lixivium of the crude kelp of Normandy, (some of which I received through the kindness of M. Gay-Lussac,) I have found that the filtered solution, when evaporated, does not, by crystallization, divide exactly between the iodic salts and the other salts; the latter, when they crystallize, are more or less mixed with the former, and increasingly so, as successive crops of crystals are obtained. After the first copious crystallization of salts, I have found it advantageous, to evaporate the remainder, at once, to dryness; this forms a beautiful white mass, which can be reserved in glass vessels and used for affording iodine whenever there is occasion.

† First Prin. I, 88. Dr. Thomson states, that as sold, it is only 2.915, owing, as he conceives, to a little water.

‡ Fluorine has been included in the same class, but its distinct existence is not yet proved.

denses again, as soon as the glass grows cold, and forms brilliant steel gray crystals, with a lustre perfectly metallic. These are dissipated anew by heat, forming the violet vapor, and this is in turn promptly condensed by cold.* It cannot be retained by a cork;† it must be kept in bottles with good ground stoppers.

(j.) The vapor of iodine is more dense than any aëriform body, being by calculation 8.678, or by actual observation 8.716, air being 1. and therefore 100 cubic inches of it should weigh about 263 grains, and is about 124 or 125 times as heavy as hydrogen.

(k.) Volatilized by the heat of boiling water, and owing to its affinity for the aqueous vapor, passes over with it; it is purified by distillation with water.

(l.) It destroys vegetable colors, but with less energy than chlorine.

4. EQUIVALENT NUMBER.—Estimated by Dr. Thomson at 124; it has been generally stated at 125, and it is not easily settled which number is correct.

5. TEST.

(a.) The peculiar color and odor of the vapor is very decisive, but we cannot always obtain this indication, even when iodine is present in considerable quantity.

(b.) Starch is by far the best test. Make a dilute solution with boiling hot water, and use it cold; put some of the substance to be examined in the bottom of a wine glass, and pour the solution of starch over it; then add a few drops of sulphuric acid by little and little, letting it run down the side of the glass; a blue color, more or less intense, and sometimes only violet, will be produced, which is owing to a combination between the iodine and the starch; this is said to receive a blue tinge from $\frac{1}{125}$ part of its weight of iodine.‡

* The best method which I have found of crystallizing iodine, so as to form large crystals, is this. Take a glass tube as large as a thumb, sealed at one end; introduce a considerable quantity of iodine; by the blowpipe, draw it out at the other end, so that it can be easily closed by fusion; vaporize the iodine till it fills the tube and is seen rushing out in vapor at the capillary orifice; then quickly close it by the blowpipe; put it in a cold place and the whole will collect in a few large and brilliant crystals, which can thus be perfectly preserved.

† Although the cork is carefully bound around with thick clay lute and several folds of linen and twine, it will corrode the whole and escape in the course of some months, even in the winter season.

‡ By this test, I have examined nearly all the varieties of sea weed which are found on the sea shores near New-Haven. I dried and burned the plants, lixiviated the ashes and separated the crystallizable salts as far as practicable; then the solid substance obtained from the evaporation of the residuum to dryness being treated as described in the text, I obtained decisive indications of iodine from every variety except the *zostera marina*, (vulgo, eel grass,) "which is abundant on every coast; it is not a true sea weed, but a phenogamous plant, and iodine appears to be found only in cryptogamous marine vegetables." (Dr. Torrey.) The *fucus vesiculosus*, gives a great deal of iodine; the dulce,* used externally in swellings, is rich in it, and the *fucus palmatus* is said to contain it; were there occasion, there is no doubt that iodine might be advantageously extracted from our marine plants.

* Popular name—botanical unknown.

6. *Action of oxygen;*

(a.) *There is none under common circumstances, but it has been recently ascertained that the vapor of iodine unites with heated oxygen gas, and forms a peculiar oxide of a yellow color. (See page 76, note.)*

(b.) *It acquires oxygen from euchlorine gas, and it is converted into*

IODIC ACID.

(a.) A, a vial containing chlorate of potassa.

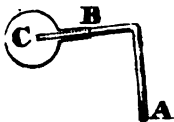
B, a spoon with a little iodine.

A little muriatic acid is poured upon the chlorate, which, especially if the vial is immersed in warm water, disengages the euchlorine, and then the metallic spoon is let down and the iodine which it contains is immediately converted into iodic acid.



(b.) Or, fill a flask with euchlorine, in the manner already described, and then introduce the iodine.

(c.) Sir H. Davy obtained it in an apparatus of this form, shaped like the letter (J) inverted, and connected with a thin long necked receiver. In the closed end of the tube, which should be the longest, we put 100 grs. chlorate of potassa and pour over it 400 grs. muriatic acid, sp. gr. 1.105. Some muriate of lime, in dry paper, is placed in the tube at B, (which is elongated by another smaller tube,) and 40 grs. of iodine in the receiver at C. The muriatic acid, aided by a gentle heat applied cautiously to the bottom of the tube, disengages euchlorine, which acts on the iodine at C, and forms iodic acid and chloride of iodine.



(d.) *This is effected by the union of the oxygen of the euchlorine with one portion of the iodine, while the chlorine unites with another and forms a chloride of iodine, of an orange color; this is easily vaporized by heat, and a white substance remains, which is the anhydrous iodic acid.*

(e.) *Properties.*—A white semi-transparent solid; taste acid and astringent; inodorous; very soluble; deliquescent in moist, but permanent in dry air; reddens and destroys vegetable blues and gives a yellow tint to other vegetable colors; sinks in sulphuric acid; by heat detonates with combustibles; from 500° to 600°, fused and volatilized, and by a higher heat is decomposed into oxygen and iodine; unites with several of the acids, (probably with all that it does not decompose,) as the sulphuric, nitric, phosphoric and boracic, and with the three first, forms crystallizable compounds; sulphuric acid dropped into the hot aqueous solution, precipitates the acids, in solid combination, having very acid properties; it is decomposed by sulphurous, phosphorous and hydriodic acids, and by sulphuretted hydrogen,

the oxygen being attracted away and the iodine liberated. The deliquesced or hydrous acid may, by careful evaporation, be obtained again in the solid state. *The solution corrodes all the metals, even gold and platinum, and especially gold. With alkalies and alkaline earths and their carbonates it forms iodates, which will be most conveniently described with the hydriodates.*

(f.) *Equivalent number and composition.*—From the quantity of oxygen obtained by the decomposition of the acid by heat; either from the free acid, as by Sir H. Davy; or from the decomposition of iodate of potassa forming iodide of potassium, as by Gay-Lussac; it has been inferred that this acid consists of iodine 1 proportion, 124 + oxygen 5, = 40 = 164, which is therefore its representative number.*

IODOUS ACID.‡

1. *DISCOVERY.*—By Prof. Sementini of Naples.†

2. *PREPARATION.*—By rubbing together, in a porcelain mortar, equal parts of chlorate of potassa and iodine, till they form a fine pulverulent yellow mass, in which the metallic lustre of the iodine is not discernible; this mass is then distilled in a glass retort, and the iodosous acid, formed by the action of the oxygen of the chlorate upon the iodine, rises in a white vapor and condenses in a yellow fluid, falling in drops into the receiver.

3. *PROPERTIES.*—Consistence oily; taste acid and astringent, leaving a burning sensation; odor like that of euchlorine; reddens but does not destroy vegetable blues; volatilized at common temperatures and rapidly at 212° , but without decomposition; soluble in alcohol and ether; decomposed by being heated with sulphur, but without detonation; by mere contact inflames phosphorus and potassium.

HYDRIODIC ACID.

1. *Remarks.*—This acid is interesting and important, because iodine exists in nature, chiefly in this form, combined with bases, and forming hydriodates. The attraction of iodine for hydrogen is strong, as is manifested by many facts.

2. *PREPARATION.*

(a.) Pass hydrogen gas and vapor of iodine, through an ignited porcelain tube, or heat iodine in hydrogen gas; an expansion of volume takes place, and this acid gas is formed, which if water is pres-

* Sir H. Davy, Phil. Trans. 1815.

† There appears some reason to believe that the product of the action is in this case, iodic acid, combined with potassa, and chloride of iodine. Heated oxygen gas and vapor of iodine, are said to combine into a yellow oxide, of the consistence of a solid oil which continues to absorb more oxygen, and passes to the condition of iodosous acid, but these compounds have not been accurately examined. Turner, 2d Ed. p. 304, quoting Edin. Jour. No. 12, p. 352, and Quar. Jour. N. S. I, p. 478.

‡ English Quart. Jour. Vol. XVII, p. 381.

ent, is rapidly absorbed and forms a strong liquid acid ; by dissolving iodine, it becomes tawny.

(b.) A glass jar of small dimensions with a tight stopper is pushed down into the mercurial cistern, until it is full or nearly so of mercury ; then a piece of wet phosphorus is laid on the mercury, just within the neck ; it is covered with iodine, and the stopper instantly replaced ; hydriodic acid gas is formed, and gradually displaces the mercury in the jar.



(c.) *The usual process is to heat gently in a glass retort, moistened iodine with about* $\frac{1}{12}$ of phosphorus, when the gas distils over ; the hydrogen being supplied by the decomposition of water, whose oxygen goes to acidify the phosphorus.*

(d.) *Hydriodic acid gas is received in jars filled with mercury, but is soon decomposed by that metal,† which absorbs the iodine to form an iodide, and liberates hydrogen gas equal to one half the volume of the acid gas.*

(e.) *Better received in empty dry bottles, in the way recommended for muriatic acid gas, (Vol. II, p. 2,) as by its great gravity it easily displaces the atmosphere.*

3. PROPERTIES.

(a.) *Colorless, very acid, resembles muriatic acid gas, and was at first mistaken for it ; like it, very largely absorbed by water, and cannot be collected over that fluid.*

(b.) *Reddens vegetable blues, but does not destroy them ; sp. gr. by calculation 4.339, by experiment 4.443 ; 100 cubic inches of it weigh 132.36 grs. it being the heaviest permanent æriform fluid known.‡*

(c.) *Oxygen gas heated with the hydriodic acid gas, takes its hydrogen to form water, and liberates the iodine ; chlorine does the same, even at the common temperature, forming muriatic acid.*

(d.) *This gas is hostile to life, and to combustion.*

(e.) *The fluid acid in its most condensed state, has the sp. gr. 1.7. In consequence of the superior affinity of iodine for hydrogen, the liquid acid is obtained by passing sulphuretted hydrogen through a Woulfe's bottle, containing finely divided iodine in a state of suspension ; heat the liquid to expel sulphuretted hydrogen, filter it to separate sulphur, and the acid is pure ; at 262° the acid distils over ; until it reaches 257°, water only rises.*

(f.) *The solution decomposes spontaneously in the air, by yielding its own hydrogen to the atmospherical oxygen, while the iodine is precipitated. Sulphuric and nitric acids decompose it immediately, evolving iodine.§*

* Dr. Ure says one fourth, Dr. Henry one sixteenth of phosphorus.

† And by all others except gold and platinum.

‡ The vapor of iodine is heavier, but it is very transient.

§ With strong nitrous acid, it takes fire.

(g.) With lead, it gives a beautiful orange precipitate; with peroxide of mercury, one that is red; with nitrate of silver, one of the same color, but more intense.

(h.) *With solution of platinum, there is produced a fine red color, growing deeper and deeper, till it resembles red wine, and in a few hours there appears a splendid pellicle of metallic platinum, covering the fluid. It is a much more sensible test of platinum, than either muriate of tin or muriate of ammonia.**

(i.) *When mixed with proto-phosphuretted hydrogen, both gases are condensed into white cubical crystals, which are volatilized, at a moderate heat without fusion or decomposition.†*

(j.) *Equivalent number, 125 or 126; this number is deduced from the composition of this acid which is supposed to be, hydrogen 1 proportion or volume, and iodine 1, or 1 volume of the vapor, = 124 or 125, according to different estimates of its equivalent number, and giving therefore 125 or 126 for the number of the acid. It is not known that the two combine in any other proportions, and the hydriodic acid is supposed to be in this respect analogous to the muriatic which is composed of one proportion of hydrogen and one of chlorine.*

4. POLARITY.—In its combinations with bases, this acid is *attracted like other acids to the positive pole; but when galvanized by itself, its hydrogen goes to the negative, and its iodine to the positive pole.*

CHLORIODIC ACID, OR CHLORIDE OF IODINE.

1. PREPARATION.

(a.) Sir H. Davy first formed this compound "*by admitting chlorine in excess to known quantities of iodine in exhausted vessels, and repeatedly heating the sublimate.*"

(b.) *By simply immersing dry iodine in chlorine gas, the latter is absorbed to the amount of less than one third, and a solid compound is the result.*

2. PROPERTIES.

(a.) *Color orange yellow, if the materials saturate each other; reddish orange when the iodine is in excess.*

(b.) *Solid, crystalline, deliquescent, fusible into an orange colored liquid, and by heat, exhales a vapor of a similar color; it is very volatile.*

* The hydriodic acid, used in this experiment, is easily formed by placing iodine and phosphorus beneath water in a tube; when gently warmed, there is an effervescence of hydriodic acid gas, and I have seen a bright flash of phosphuretted hydrogen at the tube's mouth. The solution of hydriodic acid formed in this way, may be kept the year round, and although containing phosphorous acid, it answers well for metallic precipitations; it is often colored at first, owing to an excess of iodine, but it becomes clear in no long time. See Am. Jour. Vol. VI, p. 376.

† Ann. de Chim. et de Phys. Tom. VI, p. 305.

(c.) *Solution*, in water, colorless and very acid; *reddens and then destroys vegetable blues*, dissolves more iodine and acquires a deeper color, which it loses by agitation with chlorine.

(d.) *Supposed, by Gay-Lussac, to be* a peculiar compound of iodine and chlorine, or a *chloride of iodine*. It is perhaps not proved that in its dry state it is acid, and it is thought that its acid properties may be derived from the decomposition of water producing iodic and muriatic acids, and an acid exactly similar, was produced by Gay-Lussac, by the mixture of these two.

(e.) *It does not combine with the bases to form salts*, and wants therefore one of the characteristic properties of acids; an iodate and a muriate are formed by adding it to an alkaline solution.

IODATES AND HYDRIODATES.

IODATES—consisting of iodic acid and bases.

1. GENERAL CHARACTERS.*

(a.) Great resemblance to the chlorates; the chloric and iodic acids are also very similar in composition.

(b.) Decomposed at low ignition, and liberate oxygen gas, leaving a metallic iodide or even evolving iodine and leaving the base.

(c.) Deflagrate with combustibles.

(d.) Agents that readily attract oxygen decompose the iodates and liberate iodine; such are sulphurous, phosphorous, muriatic and hydriodic acids.

(e.) Sulphuretted hydrogen gas, passed in a stream through a solution of an iodate converts it into a hydriodate, by yielding hydrogen to the iodine, and separating the oxygen.

(f.) No iodates found native—those of alkalies soluble, the rest insoluble or sparingly soluble in water.

IODATE OF POTASSA.

1. PREPARATION.

(a.) By saturating the alkali with pure iodic acid formed as already described—but this process being troublesome, is seldom employed.

(b.) *Saturate a hot and strong solution of pure potassa with iodine*; both iodate and hydriodate of potassa are formed by the decomposition of water which affords oxygen to a part of the iodine, and hydrogen to the rest, and both the acids combine with the alkali.†

Evaporate to dryness by a gentle heat; when cold, add alcohol, sp. gr. .820, which will dissolve the hydriodate and leave the iodate, in small white granular crystals.

* Dr. Turner and Davy, in Philos. Trans. II, 1814.

† Sir H. Davy supposed the iodates to be triple compounds of the base iodine and oxygen. Phil. Trans. 1824.

2. PROPERTIES.

(a.) *It deflagrates on burning coals*; heat decomposes it and gives 22.59 oxygen, and 77.41 of iodide of potassium remain. It is soluble in $13\frac{1}{4}$ parts of water at 60° Fahr.

(b.) *Its composition* is, potassa 22.246, iodic acid 77.754.—*H.*

The iodate of soda is formed in the same manner as the iodate of potassa. It is anhydrous—is in cubical grains, and consists of soda 15.9, and iodic acid 84.1.

The iodate of ammonia is formed by mingling iodic acid and ammonia or its carbonate; its crystal is a cube, and it is soluble and deliquescent; it follows the general characters, but when decomposed by heat, gives out equal volumes of oxygen and nitrogen, besides, iodine; and water must doubtless be also formed. On ignited coals, it detonates with a feeble violet flame; heated in close tubes, it often causes them to burst. *Composition*, 100 acid, + 10.94 ammonia, or gaseous ammonia 2 volumes, 1 volume iodine vapor, and $2\frac{1}{4}$ of oxygen.

All the insoluble iodates may be formed from this by double decomposition—for instance, the iodate of baryta, by mingling iodate of potassa with muriate of baryta. Iodate of baryta is formed also by adding iodine to a barytic solution, when it falls as a white powder, and consists of acid 100, and baryta 60.62.

HYDRIODATES—composed of hydriodic acid and bases.

1. GENERAL CHARACTERS.

(a.) Formed by adding hydriodic acid to the solutions of alkalies and alkaline earths; the products are soluble in water.

(b.) Also by adding iodine to those solutions and separating the hydriodate from the iodate in the manner already described.

(c.) Not changed in the air.

(d.) Decomposed by sulphuric and nitric acids; and by chlorine the acid itself is decomposed, yielding up its hydrogen, and thus liberating iodine.

(e.) The hydriodates of potassa and soda alone are found native, and of these, the hydriodate of potassa is the most common.*

HYDRIODATE OF POTASSA.

1. PREPARATION.

(a.) *By saturating the acid with the alkali.*—The usual mode of formation has been already described. Dr. Turner has given the following improved process.

(b.) *After saturating the hot aqueous solution of potassa with iodine, pass through it a stream of sulphuretted hydrogen gas, to con-*

* Dr. Turner and Sir H. Davy, in Phil. Trans. 1814.

vert the iodate into hydriodate of potassa, and to change to hydriodic acid, the free iodine which renders the fluid brown; when the liquid is limpid, the excess of sulphuretted hydrogen is expelled by a gentle heat, and after filtering, the free hydriodic acid is saturated with potassa.

2. PROPERTIES.

(a.) *This is the most important of the hydriodates; it is soluble in $\frac{3}{4}$ of its weight of water at 60° , and in much less at 212° .*

(b.) *Very soluble in alcohol; exists, as is believed, only in solution, and mere crystallization, or perfect desiccation causes the oxygen of the potassa to unite with the hydrogen of the acid, to form water, while the iodine remains in union with the potassium, forming an iodide of potassium, in perfect analogy with the muriates and chlorides.*

(c.) *Its solution, in common with that of all the hydriodates, dissolves a great deal of iodine, and thus acquires a brown color.*

Its composition is hydriodic acid $100 +$ potassa 37 .*

IODIDE OF POTASSIUM.

1. FORMATION.

(a.) *This compound is very easily made, by simply covering with iodine, a piece of potassium, lying on a copper plate; the action is generally spontaneous, and is often attended by combustion, and even explosion, which throws the burning metal about in jets, accompanied by violet fumes.†*

(b.) *Formed also by heating the iodate, and by crystallizing the hydriodate of potassa; the theory of both these facts has been already given.*

2. PROPERTIES.—*Easily fusible, and volatilized below ignition; deliquescent, readily soluble in water, but by the decomposition of that fluid, becomes a hydriodate, just as a chloride becomes a muriate, and again by a pretty strong heat, in close vessels, becomes an iodide, as a muriate becomes a chloride.* Soluble in good alcohol, without change, and by gentle evaporation, small cubical crystals of iodide of potassium are obtained, composed of 1 proportion of each of the constituents, potassium $40 +$ iodine $125 = 165$ for its equivalent number.

* * * * * * *

Hydriodate of soda, and iodide of sodium are so analogous, in their history and properties, to the similar compounds of potassa and

* Or, $100 : 88 :: 126 : 48$, which nearly corresponds with the equivalents of the acid and alkali.

† In one case, in my own experience, a test tube, containing the substances, being held over a candle, there was a violent action, with a loud report; the tube was broken and a deep brown stain was left on the finger and thumb by which it was held.

potassium, that it is not necessary to pay any particular attention to them.

* * * * *

Hydriodate of ammonia is formed by mingling the aqueous solutions of the two bodies; it is composed of equal volumes of the two gases, and yields cubical crystals, subliming in close vessels, without decomposition, like sal ammoniac.—*Henry*.

* * * * *

Iodide of ammonia is formed by the contact of iodine with dry ammoniacal gas; it passes from a metallic aspect to deep brownish red.—*Id.*

IODIDE OF NITROGEN.

1. PREPARATION.

(a.) *No direct action*; formed by adding iodine, previously ground fine in a glass mortar,* to good strong liquid ammonia; the change takes place in a short time; even a few minutes are sufficient for 8 or 10 grains; it is then thrown upon a filter, washed and allowed to dry gradually, by remaining several hours or through the night in a warm room.

(b.) *By passing ammoniacal gas over iodine*; a thick brown fluid results, which, on being dissolved in water, lets fall the fulminating iodine.

2. PROPERTIES.

(a.) *A black or dark brown powder, which is so explosive that it is scarcely possible*, after it is thoroughly dry, *to move the filters without causing a detonation*: it often tears them to pieces during its spontaneous drying.†

(b.) Explodes by the gentlest heat, and by its own friction; also on an anvil under the mere weight of the hammer, (for it scarcely needs a blow,) especially if a little dry sand be mingled with it. When it explodes, it emits a flash of light with heat.

3. COMPOSITION.—*In consequence of the decomposition of the ammonia*, hydrogen, with a portion of the iodine, forms hydriodic acid, while the nitrogen, with another portion, produces the fulminating compound.

It is supposed by M. Colin to consist of 1 proportion of nitrogen 14, + 3 of iodine $125 \times 3 = 375 = 389$ for its equivalent number.

* This circumstance I find necessary to a uniform and speedy change of the iodine into the fulminating compound; if the iodine is dropped in, in its usual state, it becomes partly fulminating, and remains partly unchanged.

† It is best, while holding the filter by its edges, to detach the powder before it is thoroughly dry, by gently bending and curving the paper, when it may be received, in portions, on several separate cards, and thus there is a greater chance of having some of it remain till it is wanted.

*We cannot fail to be struck with the analogy between chlorine and iodine, in forming each a powerful detonating compound with nitrogen.**

IODIDE OF SULPHUR.

Formed with the greatest facility, by fusing a mixture of iodine and sulphur. The compound has a dark metallic and radiated appearance, like the sulphuret of antimony. It is decomposed by a degree of heat greater than that by which it was formed, and both constituents rise in vapor. Its precise constitution is not known.

IODIDE OF PHOSPHORUS.

1. PREPARATION.

(a.) The formation of this compound under water and the production of hydriodic acid have been already mentioned.

(b.) *When dry, the two substances unite spontaneously with a vigorous action, and with considerable heat, but, as is asserted, without light, provided the air is excluded.*

(c.) *I have never failed to see brilliant light, if the experiment is conducted in the following manner; a piece of phosphorus is placed in a wine glass and quickly covered with iodine, by sliding it from a spatula or a folded paper; immediately the combination takes place with a splendid combustion,† and iodine vapor, mingling its fine violet with the white flame of the phosphorus, forms a beautiful experiment. The substances unite in several proportions; with 1 phosphorus and 8 iodine, the color is orange and the compound melts at 212° ; with 16 iodine it is grayish black and melts at 84° ; with 24 iodine it is black and partially fusible at 115° .—Murray.*

(d.) *The compound of iodine and phosphorus, thrown on a hot shovel, produces a splendid combustion, with fine iodic vapors.*

HYDRO-CARBURET OF IODINE.

1. DISCOVERY AND PREPARATION.

(a.) *Mr. Faraday‡ exposed iodine, in olefiant gas, to the solar rays, and colorless crystals were formed; no hydriodic acid was produced; the residuary gas was simply the olefiant, and therefore the new compound was a ternary one, of iodine, carbon and hydrogen. The new body was purified by being washed with a solution of pure potash.*

* M. Sérullas thinks that both these compounds contain hydrogen; "or in other words, that they are chloride and iodide of ammonia." *Le Globe*, Avril, and *Lond. Phil. Mag.* Aug. 1829.

† The light probably arises from the combustion of the phosphorus, while the heat that brings on the combustion is evolved from the combination of the two bodies.

‡ *Phil. Trans.* 1831.

(b.) *Formed also, by M. Sérullas,* by the action of potassium upon the alcoholic solution of iodine, and by adding this last to a similar solution of potassa. It will appear in the section upon alcohol, that this fluid is now regarded as a compound of water and olefiant gas, or of 1 proportion of oxygen, 2 of carbon and 3 of hydrogen. It is supposed that the elements of the water go to form iodic and hydriodic acids, while a portion of the iodine unites with the nascent olefiant gas and forms the peculiar compound.*

(c.) Mr. Scanlan obtained it by adding potassa to the alcoholic solution of iodine; theory similar.—*Murray.*

2. PROPERTIES.

(a.) The compound of Mr. Faraday is a *white crystalline body; sweet and aromatic; sinks in sulphuric acid, of the sp. gr. 1.85; friable; a non-conductor of electricity; melts and sublimes unchanged, condensing in transparent prismatic or plated crystals.*

(b.) *With a high heat evolves iodine; not very combustible, but burns in the flame of a spirit lamp, emitting iodine and hydriodic acid; insoluble in water and in acids and alkalies; soluble in ether and alcohol, and crystallizable from these solutions; the alcoholic solution is sweet, but biting and sharp.*

(c.) The substance obtained by M. Sérullas was of a yellow color and in scaly crystals, with a pearly lustre; that procured by M. Scanlan was similar but smelled like saffron.

3. COMPOSITION.—According to Mr. Faraday,† it is iodine 1 proportion, 124 + olefiant gas 1, 14 = 138, which is the equivalent number.

Mr. Faraday was led to the discovery of this substance in consequence of his success in forming the chlorides of carbon by exposure of mixtures of chlorine and olefiant gas to the sun's rays.‡

The bodies formed by iodine, and its compounds with the metals, will be mentioned in giving the history of those substances; some of them are possessed of very lively and agreeable colors, and have been applied in the arts as pigments or dyes.

POLARITY.—We have already mentioned, that *iodine belongs to the positive pole of the electro-galvanic arrangements, and that it is in this respect similar to oxygen, chlorine, and bromine, the only simple electro-negative bodies.*

Still, when the compound of chlorine and iodine is galvanized, the iodine is attracted to the negative and the chlorine to the positive pole.

* Ann. de Chim. et de Phys. Vols. XX and XXII.

† English Jour. of Sci. Vol. XIII.

‡ Phil. Trans. 1821, 72.

NATURE OF IODINE.

1. It is, as far as our knowledge goes, *an element*, no fact having yet proved it to be compound.

2. *It has analogies to other principles*, but is on the whole a peculiar substance.

3. *Its affinities are very numerous and energetic*, and it consequently forms many combinations.

4. *It resembles the metals by its weight, lustre and color, and by its high equivalent number*, (124 or 125,) there being only four metals that have higher equivalents, namely, gold 200, mercury 200, columbium 144 and uranium 208.

5. Although *a heavy solid*, it is *volatile and odorous*.

6. It has been *called a supporter of combustion*, but *its agency in this way seems limited*; potassium and a few other things burn in it with the usual phenomena of combustion; in its power of uniting with combustibles and metals, it resembles sulphur, phosphorus, and potassium.

7. *In its chemical affections it is very analogous to chlorine*.

(a.) It forms, like that body, one acid with oxygen and another with hydrogen.

(b.) It destroys vegetable colors.

(c.) *It produces, with the fixed alkalies, salts, which, by their action on combustibles, strongly resemble the chlorates*.

(d.) *The iodides have close analogies with the chlorides; the hydriodates with the muriates; the iodic acid with the chloric; the hydriodic with the muriatic; and the electrical relations of the two bodies are the same*.

(e.) Its discovery has been considered as affording strong support to the view which regards chlorine as a simple substance.

8. *Chlorine, iodine and sulphur, resemble each other*, in forming with oxygen acids whose principles are more strongly united, while with hydrogen they form other acids whose elements are more easily detached.

9. Sulphur attracts these principles in the following order; oxygen, iodine, chlorine, the first having the strongest attraction.

10. With respect to hydrogen the order of attraction is reversed.

11. Iodine resembles the metals in its physical, and oxygen and chlorine in its chemical properties.

12. It must not be omitted here, although it is mentioned by anticipation, that iodine bears a great resemblance to bromine, which will be next described.

USES.

(a.) *Iodine is a beautiful subject of philosophical experiment*; many of the phenomena connected with it are brilliant and all are instructive. After oxygen, hydrogen and chlorine, perhaps no element has such extensive alliances, although only a comparatively small number of its compounds has as yet been found native; but, it may be expected that it will be increased.

(b.) *In the arts*, as already mentioned, *it forms fine colors, pigments and dyes*. The proto-ioduret of mercury has been used in England, as a substitute for vermilion, in the preparation of paper hangings, and a compound of hydriodate of potassa 65, iodate of potassa 2, and ioduret of mercury 33=100, has been employed in printing calico.*

(c.) *In medicine it is a very active remedy*.—Indeed it is a strong poison; 6 grs. proved almost too much for M. Orfila, producing nausea, vomiting, &c.; but he was relieved by large doses of mucilage, enemas, &c. and was only slightly unwell the next day. 70 or 80 grs. killed dogs in 4 or 5 days. The tincture, 48 grs. to 1 oz. of alcohol, is a powerful remedy in goitre and other glandular diseases. The dose of the tincture is from 10 to 15 drops for an adult, taken three times a day, in syrup. The hydriodate, with excess of iodine, is preferred by Dr. Coindet; 36 grs. of the hydriodate and 10 of iodine are put into 1 oz. of distilled water, and from 6 to 10 drops of the solution are taken three times a day in half a glass of water. Iodine is so powerful, in its action on the system, that caution is requisite in its administration.† It is also applied externally in glandular affections, but it has been known to obliterate some important glands.

NATURAL SOURCES OF IODINE.

A very able investigation of the sources of iodine in nature, was published by M. G. Claubry in the Ann. de Chimie, Vol. XCIII, pp. 75, 118. He ascertained that it exists ready formed in several varieties of fucus, particularly in the fucus saccharinus, and that the only use of the incineration is to destroy the vegetable matter, and by separating the crystallizable salts by lixiviation, we obtain the iodic salts in a concentrated state. The *fucus serratus*, and *fucus digitatus*, contain a hydriodate ready formed, and most sea weeds afford it, as the fucus nodosus, and palmatus. Fyfe, Edinb. Jour. VI.‡ Starch, as already mentioned, is the usual test, and

* Am. Jour. Vol. XV, p. 394.

† Dr. Coxe's Dispensatory. Am. Jour. Vol. II, p. 395.

‡ I have obtained it abundantly from the fucus vesiculosus.

it detects iodine in the juices of some plants, in others only after incineration. It exists in sponge, and hence the use of burnt sponge in bronchocele. It is said to exist in peat, in the oyster, and in some other marine molluscous animals. It has been found in some mineral springs, as at Sales in Piedmont, which had long been famous for the cure of goitre, and scrofulous affections. It has been recently discovered in the mineral waters of Saratoga, New York. *Am. Jour.* Vol. XVI, p. 242. Mr. Tennant found it in the sea water; it has been discovered in common salt. *Murray's Chem.* Vol. I, p. 707. Vauquelin found it in the proportion of 18 per cent., in the silver ore, called the virgin ore of serpentine, supposed to be from a mine in Mexico.*

Its true source appears to be in the mineral kingdom, whence it is transferred to the vegetable, and it is therefore probable, that it will hereafter be found in other combinations.

I examined the bittern of the Syracuse salt fountains in the interior of the state of New York, without finding iodine, and Mr. Smith was not successful in detecting it in the samphire, a marine plant, which grows about the New York salines. *Am. Jour.* Vol. XV, p. 12.

It is probable that the properties of mineral waters, and of common salt, are often affected by the presence of iodine.

It is remarkable that so many of the most active and important elementary bodies should have been discovered within fifty years of each other, and within little more than sixty years of the present time: hydrogen 1766; nitrogen 1772; oxygen and chlorine 1774; potassium, sodium, and the metals of the earths, 1807-8; iodine, 1812, and bromine, 1826.

Without a knowledge of these bodies, the *science* of chemistry would scarcely be said to exist.

Mr. Fyfe obtained iodine from the *ulva umbilicalis*, from a species of *conserva*, from the *plantago maritima*, and *arenacea peploides*. The common sponge of the shops gave iodine vapors, by pouring sulphuric acid upon the ashes of the substance. The iodine in sponge is not in a condition to be dissolved out by infusion in water, for the sponge after soaking in water yields iodine from its ashes, and the infusion of the *fucus serratus* and *fucus digitatus*, affords iodine by sulphuric acid aided by heat.—*Fyfe*.

* *Ann. de Chim. et de Phys.* Vol. XXIX, and XCIX.

BROMINE.

1. NAME.*—From *βρωμος*, in allusion to its disagreeable odor.

2. HISTORY.—*Discovered by Mr. Balard*, a young chemist of Montpellier, whose account of it appeared in 1826.†

As in its properties, it bears a strong analogy to chlorine and iodine, it appears to have, in general, similar natural associations, being found in the waters of the sea, and of saline springs.

3. EXTRACTION.

(a.) *Bromine exists in sea water, in the state of hydro-bromic acid*, united as its discoverer believes, to magnesia.

(b.) *Chlorine detects bromine by uniting with the hydrogen of the hydro-bromic acid*, and thus liberating the bromine.

(c.) *Through the concentrated washings of the ashes of marine plants, or the uncrystallizable fluid of the salt pans called bittern, pass a stream of chlorine gas, and the bromine will be indicated by a deep reddish yellow color and a peculiar odor.* At ebullition, the volatile vapor, which in color resembles that of nitrous acid, will rise, and being made to pass over dry muriate of lime, is condensed in an ice-cold receiver.

(d.) *A better process is by ether, potassa, and sulphuric acid; thus; through the bittern liquor pass chlorine gas; agitate it with sulphuric ether, which should fill the flask, and will dissolve the bromine; after repose, it will float, exhibiting a fine hyacinth red color. Next, agitate the ethereal solution with some potassa; the ether‡ will lose its color and the bromine, in the condition of hydro-bromic and bromic acid will combine with the potassa.* If the alkaline solution is strong, bromate of potassa will precipitate, and on evaporation, cubical crystals of hydro-bromate of potassa are obtained, which are distilled with oxide of manganese§ and sulphuric acid, diluted with an equal weight or volume of water. A small receiver nearly full of water is kept cool by ice, and the bromine condensing in blackish red drops, first in the cold beak of the retort, falls to the bottom of the water which is then decanted, and the bromine is again distilled from off dry muriate of lime||. The bromic vapor and a portion of that which falls in drops are dissolved, but the contiguous water is soon saturated.

* Called at first *muride* from its marine origin; then *brome* in analogy with the French *chlore* and *iode*, which in English is changed into bromine, to correspond with chlorine and iodine.

† Ann. de Chim. et de Phys. Aout, 1826.

‡ The same ether may be used again to dissolve more bromine, and thus the bromic portion of a large portion of water may be concentrated into a small compass.

§ In exact accordance both with the theory and practice for obtaining iodine; the sulphuric acid uniting with the potassa, and the oxygen of the oxide of manganese with the hydrogen of the hydro-bromic acid, liberates the bromine.

|| M. Balard's Memoir, Ann. de Chim. et de Phys. Aug. 1826.

4. PROPERTIES.

(a.) *At the common temperature, if seen by reflected light or in a mass, bromine is a fluid of a dark or blackish red color; but by light transmitted through a thin film it is hyacinth red.*

(b.) *Congeals between 0° and -4° F. and becomes brittle.*

(c.) *Volatile; a drop or two will fill an empty glass vessel with red vapors, like those of nitrous acid; boils at $116^{\circ}.5$ F.; odor intense and disagreeable, a little resembling that of chlorine; taste unpleasant and powerful.*

(d.) *Corrodes the skin and the animal texture, producing a transient yellow* stain; if the contact is continued longer, it vanishes only when the epidermis is renewed; it acts on wood and cork.*

(e.) *Very poisonous; a single drop placed in the beak of a bird killed it.*

(f.) *Sp. gr. nearly 3., sulphuric acid floats upon it; soluble in water and alcohol, but more especially in ether.*

(g.) *It is not acid; but like chlorine it bleaches litmus paper and even indigo.*

(h.) *A non-conductor of electricity; in a column of the breadth of 3 or 4 lines, it intercepts the galvanic decomposition of water; like oxygen, chlorine and iodine, IT RESORTS TO THE POSITIVE POLE of the galvanic battery; it is therefore electro-negative.*

(i.) *Not decomposed by ignition, electricity or galvanism, and therefore admitted as an elementary body.*

(j.) *A candle does not burn long in its vapor; before extinction, the flame acquires a green base and a red top.*

(k.) *Its action on metals and their oxides† is similar to that of chlorine; tin and antimony burn, and potassium flashes and explodes in it.*

(l.) *Heated in contact with potassa, soda or lime, its vapor produces incandescence, while it combines with the metallic bases and forms a bromuret or a bromide.*

(m.) *Bromine is but little soluble in sulphuric acid, and when the vessel is not perfectly tight, it can be best preserved by being kept under that fluid.*

Remarks.—There is so much analogy between chlorine, iodine, and bromine, that the latter was suspected, even by its discoverer, to be a compound of the two former; but there seems good reason to regard bromine as a new element, and this is the opinion expressed by those eminent chemists, Vauquelin, Gay-Lussac and Thénard, in their report upon M. Balard's memoir.‡ Chlorine expels bromine

* Resembling that of iodine, but less deep and permanent.

† It acts with less energy upon the oxides than upon their metals.

‡ Ann. de Chim. et de Phys. Tom. XXXII, p. 383.

from its combinations, and bromine expels iodine ; it is therefore between them in power of affinity ; it is intermediate also in its ordinary form of existence, at common temperatures, for chlorine is a gas, bromine a fluid,* and iodine a solid ; they are all colored. The resemblance between them will be still more apparent in stating the most important combinations of bromine ; for like iodine and chlorine, it possesses numerous and energetic affinities.

HYDRO-BROMIC ACID.

1. **PREPARATION.**—*This acid, as its name implies, is a compound of hydrogen and bromine ; it may be formed directly and indirectly.*

(a.) *Hydrogen gas and bromine in vapor, do not combine by the solar rays ; they unite by contact with a lighted candle or an ignited iron, but only in the vicinity of the hot body and without combustion.*

(b.) *By mingling vapor of bromine with hydriodic acid, or sulphuretted or phosphuretted hydrogen, there is an immediate decomposition, and hydro-bromic acid is generated.*

(c.) *By bromine and phosphorus, mingled and moistened ; just as happens with iodine, water is decomposed and hydro-bromic gas is generated ; a gentle heat expels it, and it is collected in dry bottles or over mercury, which scarcely acts upon it ; unlike the hydriodic acid gas which is decomposed by that metal.*

2. PROPERTIES.

(a.) *A gas, colorless and very acid ; smell pungent, and excites coughing.*

(b.) *Produces in the air white vapors, more dense than those formed by muriatic acid gas.*

(c.) *Very soluble in water ; much heat is generated during the combination, and a dense fuming acid is produced ; it is colorless, but acquires color from more bromine, which it dissolves in large quantities ; by heat, the gas is in part expelled.*

(d.) *Does not decompose water, even when its vapor is passed with steam, through an ignited glass tube.*

(e.) *Oxygen does not decompose it with the same treatment.*

(f.) *Iodine has no effect ; chlorine decomposes it, forms muriatic acid and liberates bromine in red vapors, which condense in drops.*

(g.) *Nitric acid produces a similar result, but more tardily ; probably water is decomposed and nitrous acid evolved ; it forms a kind of aqua regia, dissolving gold.*

(h.) *Tin, with a gentle heat, and potassium, spontaneously decompose it—a bromide is formed and pure hydrogen gas left.*

* And is the only permanent simple fluid, except mercury, with which we are acquainted.

(i.) In this case, the gas is diminished one half in volume, which proves that it is composed of equal volumes of bromic vapor and hydrogen gas. This is confirmed by the fact, that when hydriodic acid gas is decomposed by bromine, the hydro-bromic gas formed, occupies the same volume.

(j.) By weight, it is believed to be composed of 1 equivalent of each; 1 of bromine 75,* and 1 of hydrogen 1=76, for its equivalent.†

(k.) Hydro-bromic acid gas has a composition analogous to that of hydriodic and muriatic acid gases.

(l.) Bromine attracts hydrogen less powerfully than chlorine, but more so than iodine, as is evident from the decompositions already stated.

(m.) Oxygen and bromine have an affinity nearly equal for hydrogen; bromine cannot decompose water nor oxygen hydro-bromic acid.‡

HYDRO-BROMATES.

They are composed of the hydro-bromic acid and bases, for this acid unites with the alkalies and earths; but little is known of the salts.

Owing to the removal of the hydrogen and the disengagement of bromine, the hydro-bromates become yellow, when chloric or nitric acid, or especially chlorine acts upon them.

Solutions of the nitrates of lead, of silver, and of protoxide of mercury, (which give such fine colors with the hydriodic acid and with the hydriodates,) produce only white precipitates with these metallic salts; they are regarded as bromides.

The principal one, namely, the hydro-bromate of potassa has been already mentioned. It is formed by agitating the etherial solution of bromine with caustic potash. Its crystals are cubes; they are decomposed by sulphuric acid, which disengages the hydro-bromic acid, mixed with some sulphurous acid.

Hydro-bromate of ammonia results from mingling the two gases in equal volumes; like other ammoniacal salts, this is volatile; its crystals are long white prisms, and it becomes yellow and acid by exposure to the air.

The hydro-bromates of the earths are not much known; that of magnesia is uncrystallizable, deliquescent, and decomposable by heat; that of baryta is soluble in alcohol and in water, and forms mamillary masses.

* 75 is nearly intermediate between 36, the equivalent of chlorine, and 124 or 125, that of iodine.

† L. U. K.

‡ For other particulars respecting hydro-bromic acid, reference may be had to M. Balard's original memoir.

BROMIC ACID AND BROMATES.

1. PREPARATION.

(a.) It has been already stated, that by *agitating bromine* or its *etherial solution* in contact with *solution of potassa*, sufficiently concentrated, the *water* yields its elements to the bromine; with the hydrogen it *forms hydro-bromic acid*, and with the oxygen *bromic acid*, and *two salts* are produced, the hydro-bromate, which remains in solution, and the bromate which falls in a white powder.

(b.) *This salt, on red hot coals, deflagrates like nitre; with sulphur it detonates, by percussion; by heat, oxygen gas is expelled* and a bromide of potassium remains; it greatly resembles the iodates and chlorates.

(c.) It is so far *soluble in boiling water*, as to throw down groups of needle crystals on cooling.

(d.) *Decomposed by sulphurous acid* and sulphuretted hydrogen, which attract its oxygen; and by hydro-bromic and muriatic acids.

(e.) *Bromate of potassa does not precipitate the salts of lead*, which are abundantly precipitated by the hydro-bromate.

(f.) *The bromates of the other alkalies* and earths, except magnesia, are *formed in a similar manner*; and an aqueous solution of the compound of bromine and chlorine, placed in contact with potassa or baryta, instantly produces a bromate of the alkali or earth.

(g.) *The bromate of baryta is easily decomposed by diluted sulphuric acid*; the earth is precipitated and bromic acid remains in solution.

2. PROPERTIES OF BROMIC ACID.

(a.) *Evaporated, it becomes of a syrupy consistence*, and if the heat be pushed to extremity, it is *decomposed into bromine and oxygen*; so that water appears to be necessary to its existence; similar effects happen when the evaporation of the water in a vacuum is aided by the attraction of sulphuric acid for aqueous vapor.

(b.) *Very acid*, but not caustic; nearly inodorous; *reddens and then bleaches litmus paper*.

(c.) Nitric acid scarcely affects it; the strong *sulphuric acid*, aided by the heat which it produces, *disengages oxygen and bromine*, and thus decomposes it.

(d.) *The bromic acid precipitates white, the salts of lead and silver*, and the precipitate is soluble in a little water, while that by the hydro-bromic acid with the same metals is insoluble; like the bromate of potassa, it gives a white precipitate with proto-nitrate of mercury.

(e.) *Its composition is very similar to that of the iodic, chloric, and nitric acids*; that is, it is composed of one equivalent of bromine, 75, and 5 of oxygen, $40 = 115$, its equivalent.

(f.) No oxide of bromine appears to have been as yet discovered.

BROMIDES OR BROMURETS.

These are compounds of bromine with bases.

(a.) *Bromine has a strong attraction for metallic substances, and it acts upon some of them with more energy than iodine, but generally with less than chlorine; its action has been already mentioned with respect to tin, antimony, and potassium.*

(b.) *In the vapor of bromine, potassium disengages heat and light, and even detonates; the result is a bromide of potassium.*

(c.) *The same compound is formed by heating the hydro-bromate to dryness, or evaporating the solution until it crystallizes,* in analogy with the conversion of the muriates into chlorides, and of the iodates and hydriodates into iodides or iodurets.*

(d.) *Also by decomposing the hydro-bromic acid by potassium.*

(e.) *The bromide of potassium has a sharp taste, decrepitates by heat, and suffers the aqueous fusion unchanged.*

(f.) *Chlorine displaces the bromine; iodine cannot do it, while bromine, on the contrary, disengages iodine from the iodide of potassium, with abundant violet vapors; this settles the order of their affinities in this case, which corresponds with their relative energy in other instances.*

(g.) *The bromide of potassium, by solution in water, becomes hydro-bromate of potassa; the theory is the same as in the case of iodine and chlorine.*

(h.) *Bromine, aided by heat, decomposes most of the metallic oxides, expels the oxygen and forms bromides of the metals.*

(i.) *It has been already mentioned, that when passed in vapor over ignited potassa, soda, baryta and lime,† it acts with incandescence, evolves oxygen gas and forms bromides.*

(j.) *Bromine, in the same manner, decomposes the alkaline carbonates, disengaging both carbonic acid and the oxygen gas.*

(k.) *Bromine acts upon weak solutions of alkalies to form a bromide of the oxide; not of the base; and the bromine is easily disengaged from the combination, even by weak acids, as the acetic, just as happens with the chlorides.*

(l.) *We have already seen that with concentrated alkaline solutions, bromine, like chlorine, forms two salts, and in both cases, from the decomposition of water.*

(m.) *The bromates correspond with the iodates and the chlorates; and the hydro-bromates with the hydriodates and muriates.*

(n.) *The bromides correspond with the chlorides and iodides.*

* It is supposed that, as in the case of the muriates, the hydrogen of the acid and the oxygen of the oxide, form water, while the bromine and the metal combine.

† Magnesia and zirconia could not be decomposed in this manner.

CHLORIDE OF BROMINE.

1. PREPARATION.—*By passing chlorine through bromine and condensing the volatile vapor by cold.*

2. PROPERTIES.

(a.) *A reddish yellow liquid; its color less intense than that of bromine; odor penetrating; its taste very disagreeable.*

(b.) *Very fluid and volatile; the color of its vapor like that of oxide of chlorine, and unlike the red hue of bromine; provokes tears.*

(c.) *Metals, finely divided, burn in the vapor.*

(d.) *Soluble in water, and produces a similar color and odor to its own; it bleaches litmus without reddening it, and consists therefore of the chloride dissolved, and not decomposed and acidified.*

(e.) *The alkalis produce in this compound bromates and hydrochlorates, (muriates,) by the decomposition of water.*

BROMIDE OF IODINE.

Bromine and iodine readily unite and form a solid compound, from which heat produces brownish red vapors, condensing in crystals of the same color and in form resembling fern leaves.*

More bromine causes this compound to pass to the condition of a liquid resembling the hydriodic acid, holding iodine in solution. It is soluble in water without decomposition, and bleaches without reddening litmus. Alkalies convert it into hydro-bromate and iodate.

BROMIDE OF PHOSPHORUS.

Even in a flask filled with carbonic acid gas bromine, placed in contact with phosphorus, combines with it, emitting heat and light; a crystalline solid sublimes and a liquid subsides; the latter is a proto-, the former a deuto-bromide of phosphorus.

The proto-bromide remains fluid at -16° centigrade; it is very volatile; it dissolves more phosphorus and becomes capable of inflaming combustible bodies; water produces with it hydro-bromic acid, which is evolved in gas if only a few drops are employed, but if much is used the gas is dissolved.

The deuto-bromide of phosphorus is a yellow solid, becoming a red liquid with a mild heat, giving rhomboidal crystals by cooling, and needles by the condensation of its vapor, which is dense and pungent; water produces heat with it and generates hydro-bromic and phosphoric acids.

Chlorine decomposes both these bromides, evolving bromic vapors; bromine effects the same with the iodide of phosphorus, but iodine cannot in turn decompose the bromides of phosphorus.

* It is supposed there are two compounds.

BROMIDE OF SULPHUR.

Formed by adding bromine to flowers of sulphur.

It is a dense liquid, deeper colored than the chloride of sulphur, and like it diffuses white vapors.

On water it acts gently in the cold; with energy at ebullition, producing a slight detonation, and by the decomposition of water hydrobromic and sulphuric acids and sulphuretted hydrogen are generated.

This compound is decomposed by chlorine, which causes bromic vapors to be evolved and forms a chloride of sulphur.

BROMIC ETHER.

A drop of bromine let fall into a flask of olefiant gas disappears and produces an oily substance heavier than water, destitute of the odor of bromine and having a more agreeable odor than chloric ether. It is very volatile; is decomposed by passing through an ignited tube, deposits carbon and evolves hydro-bromic acid; it is combustible. The formation of this bromic ether is another strong point of coincidence with chlorine; there is an analogous fact with respect to iodine, but the compound appears not to possess the qualities of an ether.

MISCELLANEOUS.*

Bromine is soluble in acetic acid. Distilled with essential oils, as of turpentine and anise, it produces heat, forms hydro-bromic acid and converts the oil into a resinous matter like turpentine. Camphor is soluble in bromine and by cold crystallizes. Bromine alters the most solid colors, changing them, like chlorine, to yellow.

There can be little doubt that bromine must have medical virtues although they have not been ascertained.

M. Balard obtained bromine from the plants that grow along the Mediterranean, and particularly from those that had afforded iodine.

He found it in the ashes of some animals, especially in those of the jacintha violacea, one of the testaceous mollusca from the Island of St. Helena.†

* In the London Philosophical Magazine, for August and October, 1829, there are several notices of new compounds of bromine, or of new modes of forming them. M. Sérullas has succeeded in combining it with carbon, in which the discoverer, M. Balard, did not succeed; but these details appear not to be particularly important. Bromine is still very scarce and dear, at least in this country. I have just obtained from Paris, two vials, containing each, not more than a thimble full; the price delivered here, was eight dollars for both. Still, as bromine is an interesting body, and exists widely diffused, although it would appear in small proportion, it is not improbable that it will be obtained in greater quantities. It is said that M. Balard now manufactures it in Paris at 23 francs the ounce.

† Mr. Balard found bromine in a saline mineral water of the eastern Pyrenees, and it has been discovered by Mr. John Murray, and also by Dr. Daubeny in several mineral waters in England, particularly in those of Cheltenham and Gloucester. Mr. Murray found bromine along with iodine in the brine springs at Ingisterie, and bromine in the saline waters of Bex in Switzerland. For eighteen months past,

Nature of Bromine.

It has been rendered obvious by the preceding details, that bromine is a new principle; elementary as far as we know, and so analogous to chlorine and iodine, that it is well entitled to be ranked with them.

Its range of combination is extensive, and its energy of attraction considerable; in general, it presents with other bodies, results extremely similar to those produced by chlorine and iodine, and as the discovery of iodine and of its chemical relations, added much weight to the then new theory respecting the nature of chlorine; so the discovery of bromine has greatly confirmed the views entertained respecting both iodine and chlorine, and the three are connected by relations so intimate as to have scarcely a parallel among elementary bodies.

REMARKS ON COMBUSTION.

1. *Combustion*, as commonly understood by mankind, is the emission of heat and light, during the apparent consumption of certain bodies, or during their change to such a state, that they cease to burn.

The bodies that undergo this change are called combustible, and those that appear incapable of it are regarded as incombustible.

2. It is well known that the air is necessary to the process, and that this knowledge is generally diffused, appears in the appropriate construction of fire places, and of the furnaces of the arts.

3. *Mankind are familiar with the distinction between combustible and incombustible bodies*; they are aware, from every day's experience, that all organic and several mineral bodies, as sulphur and coal, belong to the former; and it is even known that some of the metals, as zinc and antimony, are of the same class.

4. *It is not, however, commonly understood, that all the metals are combustible, and that the rocks and stones, and even water, contain inflammable matter*, in a disguised state; and in short, that all the elementary bodies,* excepting four,† will burn.

M. Hermann has made it for sale, from the salt springs of Schonebeck. Ann. der Phys. XIV, 613.—J. G.

Dr. Daubeny discovered bromine in one of the Cheshire brine springs, and iodine in two or three of the principal; it appears to be so frequent in the English purgative springs that he concludes, it is probably absent from none of them which contain much common salt. Phil. Mag. Aug. and Sept. 1829. I am not aware that any person has yet examined our waters for bromine. It may probably be expected at Saratoga, and Ballston; at Syracuse and other places where there are saline springs, and in the residuum of our marine salt works.

It is more than probable that the active virtues of many mineral waters may depend in part upon iodine and bromine.

* The imponderables are of course excepted.

† It would confound all distinctions on the subject, to say, that these four; namely, oxygen, chlorine, iodine and bromine, are also combustible; because they combine with some or all the other elementary bodies, with emission of heat and light and change of properties.

5. *It is obvious that these remarks are founded upon the popular notions of combustion*, which are not inconsistent with philosophical views; for no discovery or principle of chemical science has subverted the common views of this process.

6. *These are, therefore, not erroneous*; they are, however, incomplete, and the only question is, how far they ought to be extended.

7. Combustion has been illustrated by many facts in the history of the preceding bodies, particularly of oxygen and the inflammables. All* the simple bodies that can burn have been considered, except the metals; and with a number of them we are sufficiently familiar.

8. *The chemical agents that have been supposed to act in combustion in a manner analogous to oxygen, are chlorine, iodine and bromine*; and the opinion has been already expressed in this work, that *in relation to combustible bodies, chlorine is entitled to a rank with oxygen*. The reason is, that it acts upon them in a similar, and often in a more energetic manner; a smaller elevation of temperature is generally sufficient, and in several instances its action comes on spontaneously, which happens more rarely with oxygen.

9. *This action is, in many cases, attended with the emission of heat and light*, and the resulting bodies bear some resemblance to those produced by a combination of the combustibles with oxygen; in a word, chlorides are in good degree analogous to oxides, and acids are also produced by chlorine as well as by oxygen.

10. Could we suppose that our earth were surrounded by an atmosphere of chlorine gas, (granting that animal life could be sustained in it,) phenomena† in combustion, similar to those which now occur, would be witnessed; and some of the effects would, in energy, surpass any thing at present known.

11. *What ground then is there for objecting to the use of the phrase supporters of combustion*; perhaps no language could be found, at once more appropriate and comprehensive.

12. *The claims of iodine to be regarded as a supporter of combustion are more limited*; an atmosphere of the vapor of this substance spread around the earth, would not produce many appearances similar to those which are now called combustion; still, its general affections assimilate it very nearly to chlorine.

13. *The newly discovered body, bromine, has a considerable claim to be admitted as a supporter of combustion*, but even this falls far

* Nitrogen, as forming oxides and acids with oxygen, is included; although no sensible light or heat is evolved, during the combination.

† Not all the phenomena however; e. g. carbon would not burn, although many compound combustibles in which it exists would prove inflammable in chlorine.

short of the general and active agency of oxygen and chlorine in this process; still, these four bodies, and the three last especially, have so many points of resemblance, that they must be classed together.

14. *Shall we, (as some are disposed to do,) extend the idea of combustion so far, as to include every case of intense chemical action, with emission of heat and light, and change of properties?*

15. It cannot be objected to this generalization, that it is unphilosophical; but its tendency is to produce confusion, and to blend cases which are otherwise distinct.

16. *If philosophers will agree upon this or some similar definition, it will soon be understood by themselves,* although it might be perplexing to learners; still, it would be difficult, even for a chemist, and much more for a novice in the science to conceive, that burning charcoal or phosphorus, undergoes a change analogous to that which strong sulphuric acid produces upon calcined magnesia; or the same acid upon chlorate of potassa;* or even water upon the best quick lime; for in all these cases there is intense chemical action, with disengagement of much heat and even of light, visible in the dark.†

17. Vapor of sulphur, as regards the emission of heat and light, produces combustion in some cases; and sulphur in substance, when combining with several metals, exhibits similar phenomena; so potassium combines with phosphorus, cyanogen and sulphuretted hydrogen, with energy and incandescence; and were such cases seen by mankind in general, they would undoubtedly be called instances of combustion.

18. *There is perhaps no strictly philosophical objection to calling them by that name;* still it appears more convenient to describe them simply as cases of combination, attended by the emergence of heat and light, especially as the results of the combination are in most cases remarkably different from those that attend the union of the same substances with oxygen and chlorine.

19. In sulphuretted hydrogen, for example, potassium forms a compound almost as combustible, as the two combining elements were before; while, after combination with a maximum of oxygen or chlorine, it will be found entirely incombustible; the same is true in a great degree of phosphorus and sulphur, combined with potassium and with the other metals; the metallic sulphurets and phosphurets are still altogether combustible. If therefore there is a change of properties in

* The light in this instance is probably owing to the decomposition of the oxides of chlorine, but the case is not, on that account, less in point.

† The two first cases are familiar experiments; the last is not so often attended to; I once saw it distinctly.

these and other analogous cases, to which many now wish to extend the idea of combustion, it is a change, in most instances, very different from that which combustibles undergo by burning in oxygen or chlorine, or according to popular ideas, in common air; and in a word, a burnt body is, in those cases, in the strange condition of being still combustible, and it does not cease to be so, until, in the usual sense, it has been burned anew.

20. Still, the principal reason why we would prefer the more restricted sense of combustion is, that it saves the student from being bewildered by a group of phenomena, agreeing indeed in the obvious facts of intense chemical action with emergence of heat and light; but disagreeing widely, in the results produced by the combination. No advantage appears to arise from the proposed generalization, and several judicious modern authors* adhere mainly to the common acceptance of combustion.

21. It is with little reason, that some writers now neglect or condemn Lavoisier's great generalization of the philosophy of combustion; for, except that the heat and light, evidently, come from all the bodies concerned, combustibles and supporters too, and not from the oxygen alone; his view remains substantially correct, and includes all the cases that mankind in general are acquainted with; although it is necessary to give more extension to the idea of combustion, so as to embrace the action at least of chlorine, and, perhaps to some extent, of iodine and bromine.

22. *After having included many cases under combustion which Lavoisier never regarded in that sense*, and which are foreign from the experience of mankind on the subject, it is easy to criticise the views of that great man with severity, and to deride them as unphilosophical.†

23. *It is still true, and must ever remain so, that all the usual cases of combustion are those in which oxygen combines with the combustible body*, and both changes its properties‡ and increases its weight; whatever additional experience may be presented in our laboratories, it is neither possible nor desirable to change the established language and notions on this subject; and science loses nothing by retaining, although she may be permitted to extend them.

* Dr. Henry, Dr. Turner, Mr. Murray. Dr. Ure, following Sir H. Davy, is zealously and ably engaged for the utmost extension of the notions of combustion.

† "It is melancholy to reflect with what easy credulity the fictions of the Lavoisierian faith have been received and propagated by chemical compilers, sometimes sufficiently incredulous on subjects of rational belief."—Ure's Dict. p. 346.

‡ One of the most important of these changes is, that the body becomes partially or entirely incombustible.

METALS.

1. DISTINCTIVE CHARACTERS.

(a.) *The best conductors of electricity and heat*; the former passes through them instantaneously, the latter progressively although rapidly. Prepared charcoal resembles the metals, in being an excellent conductor of electricity, but it is always one of the worst conductors of heat.

(b.) *Metals are determined to the negative pole in the galvanic series*, provided they are combined with oxygen, chlorine, iodine, bromine or sulphur; *and their oxides have the same destination, when combined with acids*; hence the metals are said to be *electro-positive*.

(c.) *Quite opaque*, even in the thinnest laminæ, *excepting only gold*, whose leaf transmits the green light.

(d.) *Reflect the light powerfully*; some of them in a manner superior to any other substances. This peculiar brilliancy is called the metallic lustre. Although they are the best reflectors, they are the worst radiators of heat.—*Dr. Hare*.

It has been agreed to call all bodies metals which have the above assemblage of properties, and no other bodies will be found to possess them all.

2. HISTORY AND IMPORTANCE.

(a.) *From the remotest ages ranked among the most interesting of natural bodies*; the demands of necessity, convenience and luxury, have, in all ages, given them a primary importance; and no fact in the history of nations is more indicative of a state of barbarism, than ignorance of the metals, and especially of iron, the most useful of them all.*

(b.) *The operations of war, of agriculture and the useful arts; of commerce and experimental science; and the prescriptions of medicine, are greatly dependent upon them*; and the precious metals, in the form of a circulating medium, afford the only immutable representatives of property.

(c.) *Even chemistry, at an early period, existed only in the form of alchemy*; whose great object it was to transmute the base, into the precious metals.

3. NUMBER.—*Stated by most modern authors as being about 40*. The following table, from the 11th edition of Dr. Henry's Chemistry,† with the addition of zirconium and thorium, the latter metal recently announced by Berzelius, contains 40, without including the

* Even in the pentateuch, Tubal Cain is recorded as an artificer in brass and iron, and, among various ancient nations, divine honors were bestowed on the reputed inventors of the methods of working the metals.

† Just received from the author, (Jan. 25, 1830,) and the date of the preface is but two months earlier, so that this is later than any other foreign list of metals.

basis of silica, which many suppose to be more allied to the combustibles than the metals.*

Names of Metals.	Discovered by	Date.
1. Gold,	Known since the remotest antiquity.	
2. Silver,		
3. Iron,		
4. Copper,		
5. Mercury,		
6. Lead,		
7. Tin,		
8. Zinc,	Known to Paracelsus, who died	1541
9. Bismuth,	Described by Agricola, - -	1520
10. Antimony,	Described by Basil Valentine, 15th century.	
11. Arsenic,	} Brandt, - - - - -	1733
12. Cobalt,		
13. Platinum,	Wood, Assay Master, Jamaica, -	1741
14. Nickel,	Cronstedt, - - - - -	1751
15. Manganese,	Gahn and Scheele, - - - -	1774
16. Tungsten,	M. M. D'Elhuyart, - - - -	1781
17. Tellurium,	Muller, - - - - -	1782
18. Molybdenum,	Ditto and Hielm, - - - -	1782
19. Titanium,	Gregor, - - - - -	1781
20. Uranium,	Klaproth, - - - - -	1789
21. Chromium,	Vauquelin, - - - - -	1797
22. Columbium,	Hatchett, - - - - -	1802
23. Palladium,	} Dr. Wollaston, - - - -	1803
24. Rhodium,		
25. Iridium,	Descostils and Tennant, - -	1803
26. Osmium,	Tennant, - - - - -	1803
27. Cerium,	Hisinger and Berzelius, - -	1804
28. Potassium,	} Sir H. Davy, - - - - -	1807
29. Sodium,		
30. Barium,		
31. Strontium,		
32. Calcium,		
33. Magnesium,	} Arfwedson, - - - - -	1818
34. Lithium,		
35. Cadmium,	Stromeyer, - - - - -	1818
36. Aluminum,	} Wöhler, - - - - -	1828
37. Glucinum,		
38. Yttrium,	} Davy and Berzelius, - -	1808 to 1828
39. Zirconium,		
40. Thorium,	Berzelius, - - - - -	1829

* It would not be surprising however, if silicon were to be hereafter melted, that it should prove to be a metal; for it would be extraordinary if silica among the earths

LEADING PHYSICAL PROPERTIES OF THE METALS.

The physical properties of several of the metals are not inferior, in importance, to those depending on their chemical relations, and those of the greater number are interesting and instructive.

I. THEIR WEIGHT AND DENSITY.—The heaviest earthy body, (sulphate of baryta,) does not weigh over 4.75, water being 1, and stones are usually between 2 and 3.

The superior weight of the metals, as a class, is no longer a distinctive, although it is still a general property.—Potassium and sodium float on water, and there is reason to believe that there is a tolerably regular series, of increasing weight, through the metals of the earths up to titanium, (sp. gr. 5.3,) the lightest of the metals known previously to 1807, when potassium* was discovered; and so on to platinum, the heaviest of all natural bodies, which in its state of greatest compression, is about 23 times heavier than water. If we counterpoise two tumblers in opposite scales, and then fill one with water and balance it with mercury, we shall be forcibly struck with the wide difference of volume under the same weight. With the same view, platinum may be counterbalanced by cork.

The principal uses of the great weight of the metals are: 1. In war, where their projectile force, far exceeds that of any other bodies; it depends on their momentum, which is made up of velocity and specific gravity. In ancient war, stones were used for the same purpose, but their force was vastly inferior, especially as they were thrown by hand or by machines, and not by gun powder. 2. As a moving power, especially in balances and scales, and in all other instances where a great power, in a small bulk, is wanted. 3. In the reduction of the metals themselves from their ores; for after fusion, they, in consequence of their weight, subside to the bottom, and leave the lighter impurities on the top.

II. OPACITY.—*The metals are commonly said to be perfectly opaque;* without doubt they are by far the most opaque of all bodies, but, as gold leaf transmits a beautiful green color, when held up to a

should be the only exception, and prove not to be a metallic oxide. I have not included in the list of metals one called rhenium and another pluranium, the reputed discovery of which appears to need confirmation.—London Phil. Mag. March, 1829.

* The want of weight is no valid objection against the admission of potassium and sodium into the class of metals, for titanium, the lightest of the metals before known, is but 6 times heavier than potassium, and but little more than 5 times heavier than sodium, while its specific gravity is only one fourth or one fifth that of platinum, so that this metal and columbium, whose gravity is only a fraction greater than that of titanium, may be regarded as a connecting link between the old and the new metals. It has been suggested that potassium and sodium may contain hydrogen, and thus acquire their levity, but there is no fact that proves this supposition to be true.

window, is it not probable that if the other metals could be reduced to the same thinness, they also would transmit light? This seems to indicate no other peculiarity in gold than superior malleability. Tin-foil and leaf brass, completely intercept the light, although much thinner than common writing paper, which is partially transparent, as perhaps all or nearly all other natural substances are, when reduced to very thin laminæ or flakes.

III. LUSTRE.—*This property* appears to depend on the two preceding, and, although it is not peculiar to the metals, it is *possessed by them in a most eminent degree*, as is beautifully exhibited, in clean mercury, in burnished silver and gold, and in polished steel. It is true that mica or isinglass, several of the feldspars, and some other earthy compounds exhibit, in their natural state, a considerable degree of brilliancy, and the marbles, and alabaster, the gems and most very hard stones, can be made, by polishing, to assume it in a high degree; but, if a furrow be made by scratching any brilliant body which is not metallic, it will appear dull; on the contrary, if a bright metal, (not an ore,) be scratched, the furrow is equally brilliant as the original surface. Mica is sometimes mistaken for a metal, but, it may always be distinguished in this way, and by its inferior weight. *The brilliancy and opacity of metals fit them admirably for mirrors, of which they are always the basis*;* in consequence of their opacity, they intercept the light, and, by means of the high polish which they are capable of assuming, they throw back or reflect all the rays; hence bright metals do not become heated except with extreme slowness.

Metals, if tarnished by the air, are easily brought back by friction to their former brilliancy. "The metals remarkable for permanency of lustre, in the fire and air, are gold, platinum, silver, and palladium."—*Hare*.

From Prof. Leslie's experiments, it appears that the reflecting power of the metals is in the following order, as indicated in the direct proportion of the numbers—brass 100, silver 90, tin-foil 85, planished block tin 80, steel 70, lead 60, tin-foil softened by mercury 50. Burnished steel is usually regarded as the most brilliant of natural bodies, the diamond perhaps excepted. Some metals, as cobalt and manganese, have little lustre.—*Henry*.

IV. CONDUCTING POWER.—*Metals are the most perfect conductors of electricity, heat and galvanism*; and especially when moistened with acids, or other agents, that act on them, and placed in a partic-

* Even glass mirrors are rendered effectual, only by the film of metal which is made to adhere to them; as in a common looking glass, whose reflecting power depends principally upon an amalgam of tin foil and mercury. Glass affords, therefore, in these cases, only a convenient means of suspending or spreading a thin metallic sheet; it is of itself an imperfect reflector.

ular order, they generate galvanism more rapidly than any other bodies.

They are therefore called electro-motors ; not that they are exclusively, but eminently so, for other bodies evolve this power. They might however with equal propriety be called calori-motors and magneti-motors ; as galvanic combinations, and particularly those of Dr. Hare, have proved ; for, these powers are also evolved, as will more particularly appear in the section on galvanism.

*The metals burn brilliantly, and with variously colored flames, when electric and galvanic discharges, greater than they can convey away, are received through their wires or leaves.**

V. FUSIBILITY AND CRYSTALLIZATION.—*There is a very great diversity in the fusibility of the metals ; quicksilver, except in high polar latitudes, is always fluid at atmospheric temperatures ; but as it can be frozen at -39° , F. by artificial as well as by natural cold,† it must be regarded merely as a melted metal.*

Platinum can be softened, but is not fusible in our furnaces, although it will melt under a stream of oxygen gas, directed upon burning charcoal ; and better still, in the focus of the compound blowpipe. Mercury is therefore at the bottom of the scale, and, (if we except some of the newly discovered and very refractory metals,) platinum is at the head. Between these extremes there is a very great variety ; some are infusible in furnaces, and require the heat of the compound blowpipe. Such are titanium, tungsten, chromium, and several of the more recently discovered metals : some, as iron and manganese, require a full white heat, or, the greatest heat which a wind furnace can produce ; some, as silver, copper and gold, a full red, or low white heat ; several, as lead, tin, bismuth and zinc, melt from 442° to a low red heat,‡ and there are metallic alloys which will melt even below the heat of boiling water. Melted metals retain their brilliancy and opacity, unless tarnished by the atmospherical oxygen ; their surfaces assume somewhat of a convex form, especially at the edges ;—this is owing to the cohesive attraction of their particles, and hence, if dispersed in small masses, they become globular, and readily run together again, when brought into apparent contact. For the same reason the hand is not soiled by being plunged into clean quicksilver, and as this appearance is most conspicuous in that metal, it is called the mercurial manner of fusion.

The fusibility of the metals is of the utmost consequence, for we are thus enabled to cast them in moulds, into any form, and even to produce very beautiful figures and ornaments upon their surfaces, in-

* Their power to conduct electricity, is now found to be in proportion to the mass, and not merely to the surface.—Henry, 11th Ed. Vol. I, 508.

† As has happened in Hudson's Bay, in Siberia, and in the late Arctic voyages.

‡ Alkin's Dict. Vol. II. p. 98.

stead of resorting to the tedious labor of cutting vessels from the block by the chisel, or turning them in the lathe; operations which, with respect to iron, the most important of all the metals, would be nearly impracticable. *By slow cooling, after fusion, the metals may be made to crystallize*, assuming at the same time a peculiar structure, which in bar iron, is usually fibrous,* lamellar in bismuth and antimony, and granular in steel. Crystals of native metals are generally cubes, or octahedra, or of some intermediate figure. As soon as a crust is formed on the surface of a congealing metal, it is broken, and the fluid within, is poured out, or withdrawn by a plug from below, when crystals are often found lining the inside. In the case of iron and bismuth, the fused metal is more dense than the solid, for the latter floats on the former. *Hence these metals take with great accuracy the impressions of the mould.*—Arsenic is volatilized at a low temperature, and is therefore more prone to fly away in vapor than to melt. Quicksilver is dissipated by a degree of heat not much exceeding three times that which makes water boil. The volatility of the seven following metals, in a temperature which, for the most fixed, does not exceed a red or white heat, has been distinctly ascertained, namely, cadmium, mercury, arsenic, tellurium, potassium, sodium and zinc, all of which can be distilled over from one vessel to another.

By a heat still more intense, most of the metals can be volatilized, and several of them are dissipated with great rapidity, by the compound blowpipe, by the solar focus, and by electric and galvanic discharges.

* * * * *

The cohesion of the metals is an important property, existing in very various degrees; and in some of them, it is more remarkable than in any other substances.

VI. TENACITY.—*The tenacity of the metals which depends on their cohesion, is the source of some of their most important uses in the mechanical arts*, but they possess this property in very different degrees. According to the experiments of Sickingen,†

An iron wire $\frac{1}{8}$ of an inch in diameter sustains 705 lbs. avoird.

copper,	-	-	-	-	-	-	387
platinum,	-	-	-	-	-	-	351
silver,	-	-	-	-	-	-	239
gold,	-	-	-	-	-	-	191

“The tenacity of tin is greatly inferior to that of gold, and the tenacity of lead is least of all.”

* Owing to the strokes of the tilt hammer in drawing the bar; in some varieties of iron the structure is in small plates.

† Alkin's Dict. Vol. II, p. 97.

A lead wire one tenth of an inch in diameter will not sustain 30 lbs.

Upon the tenacity of metals depend their ductility and malleability.

1. *Ductility is the power of being drawn into wire*, by causing cylindrical pieces of the metals, sharpened at one end, to pass through a series of conical holes, made in a plate of hardened steel, beginning with the larger and going on to those which are successively smaller and smaller, till the wire is sufficiently fine. In the small way, it is done by hand; in the large by powerful machinery.

2. *Malleability is the property of suffering extension under the hammer or between the rolling cylinders*.—It might be imagined that the properties of malleability and ductility are exactly correspondent, but this is by no means true. Hardness with tenacity gives great ductility, but little malleability, as in iron and platinum; if softness is joined with tenacity it produces malleability in a peculiar degree, as in gold, tin and lead, while gold and silver, being midway in their character, have both properties in nearly an equal degree.—*Murray*. Tin and lead are considerably malleable, but very imperfectly ductile; iron, in the cold, is scarcely malleable at all, but it is astonishingly ductile; it can be drawn into wires as fine as human hair; * gold, silver and platinum, possess both properties in an eminent degree. Dr. Wollaston† drew gold wires of $\frac{1}{1000}$ of an inch in diameter, 550 feet of it weighing only one grain; and he obtained platinum wire $\frac{1}{1000}$ of an inch in diameter. Gold is the most malleable of all the metals; notwithstanding its great specific gravity, it can be beaten into leaves so thin that the wind will blow them away, and silver is, in this particular, very little inferior. Gold, of the degree of thinness which it has in common gold leaf, requires but one grain in weight to cover 56 square inches, and it may be made much thinner still.

(a.) *Laminability is that modification of malleability by which metals are pressed into sheets between the rolling cylinders*.—For this purpose iron, in the form of bars flattened at one end, is ignited in long oven shaped furnaces, and when red hot, it is passed between strong steel cylinders, turned by great mechanical power.

During the compression of metals, either under the hammer, or between the rolling cylinders, caloric is evolved; iron, by rapid hammering, can be made red hot; it becomes brittle however as the other metals do, by similar treatment, and, to restore their flexibility they require to be slowly heated, or annealed; thus, iron wire is always rigid and brittle till it has been warmed, after which it may be bended without danger of breaking. It is obvious that the property of laminability, or, of being formed into plates or leaves, depends

* It is said, by Fourcroy, that perukes have been made of it.

† Phil. Trans. 1818, p. 114.

on malleability, while that of *ductility* is in the compound ratio of the malleability and tenacity.

To the tenacity of metals we are indebted for the utility of wire ; of chains, anchors, and other similar mechanical contrivances ; and to their malleability for all wrought metallic instruments.

(b.) *Intimately connected with these properties are those of hardness and elasticity*, which are not possessed, in any remarkable degree, by metals in their natural state. All the metals are scratched by many of the earthy bodies, and various earthy powders are made use of to polish them. Both elasticity and hardness, so indispensable to the most important uses of iron, are imparted in a great degree, by processes, the details of which belong to the history of the individual metals. In general, however, they consist in heating the metal and cooling it suddenly, by which means, while it becomes harder and more elastic, it is rendered also more brittle ; but, by heating it again and cooling it slowly, it may be restored to its former condition. Iron possesses, naturally, very little elasticity, but, by processes of art it may be rendered almost perfectly elastic, as in the balance springs of watches. The alloys of the metals are sometimes much more hard and elastic than the metals which enter into their composition—for instance, tin and copper are soft, and tin is not elastic, but bell metal is highly elastic and considerably hard. Iron, copper and silver, are among the most sonorous metals.

VII. COLOR, TASTE, SMELL.—*The metals have various colors, but generally shades of white, gray, and more rarely red and yellow.* Most of them affect the organs of taste peculiarly, and rather disagreeably ; as zinc and copper. Some are nearly tasteless, as silver and gold. A peculiar odor attends several of them when rubbed or handled, as arsenic, tin and lead, but these effects hardly admit of description.

The taste and odor are probably often connected with galvanic action.

VIII. MAGNETISM *does not appear to be naturally and permanently attached to any non-metallic body*, and so few of the metals themselves are permanently susceptible of it, that it cannot be regarded as a general property.

(a.) *The only permanent natural magnet is the protoxide of iron, called magnetic iron.* Every one knows, that iron, in the metallic state and in that of steel, is attracted by the magnet, and that steel can be made, by art, permanently and powerfully magnetic.

(b.) *Nickel also, when purified, is not only capable of magnetic attraction, but it can be also made to become a permanent magnet.*—This property is now ascertained to belong to cobalt* also, but

* Dr. Wollaston, (Phil. Trans. 1823, p. 400.) estimated the relative magnetic powers of iron, nickel and cobalt, to be, for iron 80 to 90, cobalt 50 to 60, and nickel 20 to 30.

the ores of nickel and cobalt are not attractable by the magnet. They become so only when purified. Magnetism is a physical power, which, on account of its relation to the metals, we here mention only incidentally.

GENERAL CHEMICAL RELATIONS.

Under this head, some leading views and facts may be given with advantage by way of introduction, but with brevity, as the chemical relations of each metal will come in turn under review.

I. OXYGEN.

1. *When the metals are heated to a certain degree, they not only melt, or rise in vapor, but, if air be admitted at the same time, most of them become tarnished, and are gradually or rapidly converted into powders of an earthy appearance, and of various colors and properties; their weight is increased, and if the process has been performed in a confined portion of air, it will be found irrespirable, and unfit to sustain combustion any farther.*

(a.) *Some of the metals undergo this change rapidly, so as to burn with the sensible phenomena of heat and light.* Thus, zinc among live coals, burns with a white and blue flame, and if previously mixed with chlorate of potassa, or nitre, it deflagrates. A mixture of iron filings and tin burns in the same manner; or if thrown into a blaze, the iron filings sparkle brilliantly.

Antimony and zinc being very volatile metals, are oxidized most rapidly while rising in vapor, and the fumes appear luminous; these phenomena are most remarkable in zinc.

Tin, being very fusible, absorbs oxygen most readily after it is melted, and with an intense heat, actually burns. The same is the fact with lead, but it requires a higher degree of heat than tin.

Lead and tin, when mixed, absorb oxygen with more rapidity than when separate, and this is true generally of mixtures and alloys of metals.

(b.) *With a stream of pure oxygen gas, directed upon burning charcoal, the phenomena are still more remarkable, and prove that all the metals are inflammable substances.* These experiments are splendidly exhibited by the compound blowpipe, which melts and burns all the metals.

(c.) *The conversion of the metals into earthy powders, is owing to their combination with oxygen, and the phenomena of burning, so far as they appear, are in these as well as in all common cases, (see. p. 96,) owing to that agent.*

(d.) *The metals combine with oxygen under very different circumstances, and some are spontaneously oxidized.*—Iron, for instance, always attracts oxygen in a damp air, but no one would say that when iron rusts, it burns. Still, in oxygen gas, iron burns with vivid scintillations, and also in the united flame of that gas and hydrogen.

Manganese and arsenic attract oxygen from the air, even when artificially dried, but Thénard asserts that potassium is the only metal which at common temperatures is oxidized in *perfectly dry* oxygen gas.

2. *Most metals require an elevation of temperature to enable them to combine easily with oxygen*; but the heat required is very different. Arsenic thrown on a red hot iron burns with flame; antimony, bismuth and tin require a full red or white heat. Gold, silver and platinum scarcely attract oxygen from the air, at any temperature, and can be combined with it only by the agency of acids, by electricity, by galvanism, or by the compound blowpipe under which they burn, either with flame or scintillation; and in powerful galvanic or electrical arrangements, as already observed, their wires and leaves are dissipated with splendid combustion.

OXIDES.

1. NOMENCLATURE.

(a.) *The substances resulting from the combination of oxygen with the metals are*, with the exception of a few cases, called *oxides*. This was mentioned under the history of oxygen.

(b.) *There are often more oxides than one of the same metal*, and they were formerly distinguished by terms referring to their colors, as the red and the black oxide of iron—the red and yellow oxide of lead, &c. This is sufficient for common purposes, but Dr. Thomson proposed to denote the extremes of oxidation in the same metal, by the term *protoxide* for the minimum, and *peroxide* for the maximum* of oxidation, and the intermediate degrees by the terms *deutoxide*, *tritoxide*, &c. from the Greek, as the *per* is from the Latin. This judicious nomenclature is now generally adopted, but it need not deprive us of the valuable aid in remembering the oxides, derived from so remarkable a sensible property as their color.

2. CALX AND CALCINATION.

(a.) *Formerly oxide was called calx, and oxidation calcination*, from a supposed analogy between the burning of lime (in Latin *calx*) and the conversion of the metals, by heat and air, into those earthy powders which are now called oxides.

(b.) *But there is no real analogy between the two cases*, for the one is a combination of oxygen, the other an extrication of carbonic acid gas. In both there is, in the results, a similarity of appearance, but the metals become oxides, and invariably with an increase of weight; while limestone, by burning, becomes quicklime, and from the loss of carbonic acid and water, diminishes in weight nearly one half.

* This was at first restricted to those cases where there were only two oxides, but now peroxide is used for the highest combination, although there may be no intermediate one between that and the protoxide.

3. **PHLOGISTON.**—*This change was formerly imputed to the escape of phlogiston, the supposed principle of inflammability, and when the oxide was restored to its metallic state, by heating it with charcoal, the phlogiston was supposed to be restored, so that, according to this opinion, all metals consist of an earthy basis and phlogiston. The increase of weight during oxidation, and the diminution during reduction, not being accounted for by this theory, Stahl, who defended and illustrated the doctrine of phlogiston, introduced by Becher, assumed that phlogiston is a principle of positive levity.*

4. **THE TRUE THEORY.**—*If for the escape of phlogiston, we substitute the combination of oxygen, and for the combination of phlogiston, the escape of oxygen, we shall then, (as has been already remarked at Vol. I. p. 126,) translate the phlogistic hypothesis into the true theory. There could have been, however, no objection to the word phlogiston, had it been restricted to the imponderable elements which, during combustion, escape in the form of heat and light, and which return again sometimes imperceptibly, and sometimes with sensible phenomena, during the reconversion of an oxydized or burned substance into a combustible.**

5. REDUCTION.

(a.) *By heat. The oxygen is sometimes separated by heat alone. The oxides of gold, silver, platinum, mercury, nickel, rhodium, osmium, iridium, and palladium, give out their oxygen in this manner, and are completely reduced.*

Other oxides, as those of manganese and lead, relinquish only a part of their oxygen by heat alone, and the aid of an elective attraction is necessary to detach the remainder.

* The opinion that the weight of metals during oxidation is occasioned by the fixation of air, appears to have been entertained by various persons at different periods, as by John Rey, a physician of Perigord, A. D. 1630; by Mayhow of Oxford, 1674; by Dr. Black, 1762; and at last it was in form asserted by M. Bayen, a French apothecary, 1774; but it was Lavoisier who finally and fully established it by numerous and decisive experiments, one of which is thus related:—

“Lavoisier placed 8 oz. of tin in a glass retort of the capacity of 250 cubic inches, whose neck was drawn out to a fine orifice. That some of the air might be expelled, and thus prevent explosion, the retort was heated till the tin began to melt; it was then sealed hermetically, accurately weighed, and placed again on the fire. The tin underwent in part, a change into an earthy powder, and when this change had ceased to proceed any farther, the retort was found unchanged in weight; but on breaking the point, the air rushed in with a hissing noise, and the retort had gained 10 grains in weight, which was afterwards found to have been all acquired by the tin. A similar experiment was made by Lavoisier with quicksilver, which in a confined portion of common air was converted in part, into red oxide, leaving the nitrogen of the air unchanged, and from the oxide the oxygen was afterwards expelled by heat, and found to be pure, while the quicksilver was recovered in the metallic state.”

Most of the metals require to be heated with charcoal in a furnace or with hydrogen gas, in a receiver by a lens; or by a current of this gas passed over the oxide in an ignited porcelain tube, or with some other substance having a strong attraction for oxygen. Charcoal is most commonly employed, both in philosophical chemistry, and in the furnaces of the arts; carbonic acid and oxide of carbon, are the gaseous products, and the metal is revived.

Black flux, a mixture of dry charcoal and carbonate of potassa, is often employed in the small way in laboratories.

(b.) *By galvanism and electricity.*—Van-Marum, by his great electrical machine, decomposed the oxides of tin, lead, zinc, and antimony.* Galvanism, aided by an affinity for mercury, has decomposed even lime, baryta, and strontia; and most of the metallic oxides, when placed between its poles, are decomposed, and give up their oxygen at the positive, and the metal at the negative pole.

(c.) *By affinity, without heat or galvanism.*—This is seen principally when the metals are in the saline form, that is, when their oxides are combined with acids. Thus, hydrogen and its varieties, reduce the oxides of lead, bismuth, and silver; phosphorus has a similar power, and one metal, by its superior attraction, both for the oxygen and the acid with which the metal is combined, will often precipitate another.

(d.) *By light*, which reduces some metallic oxides, as those of quicksilver.

6. GENERAL CHARACTERS OF OXIDES.—Their properties are very diverse.

(a.) *Most of them are pulverulent substances*, entirely different in appearance from the metals, and often differing as much from their own particular metal, as from any other. Iron rust, red lead, red precipitate, or red oxide of mercury, and white oxide of bismuth, are striking examples. The tenacity, lustre, and all the physical properties are changed; absolute weight is indeed always increased, but the specific weight is generally diminished; potassa and soda are, however, exceptions.

(b.) *Several of the metallic oxides melt into glass*, as those of lead, bismuth, and zinc, and most of them vitrify with alkaline, saline, and earthy substances, and acquire permanent, and often brilliant colors.

(c.) *Metals form not only oxides, but a few of them, with a large proportion of oxygen, become acid.* Such are chrome, tungsten, molybdenum, and manganese; arsenic gives two acids, and is said to

* Jour. de Phys. 1786, Tom. XXVII, p. 164.

be the only metal which, by combining with oxygen, does not form an oxide, but acids only.*

(d.) *Metallic oxides combine with acids, to form salts*; with the exception of ammonia, and the vegetable bases, morphia, &c., there is no saline substance, which has not a metallic oxide for its basis.

(e.) The oxides are either earths or alkalies, or oxides properly so called.†

(f.) In this view, *some are insoluble in water, some highly soluble, some acrid and active, some inert*, in their action on the living body; some change the vegetable colors, and the change is always different from that produced by an acid.

7. *In metallic oxides, the oxygen is always in definite quantity,† and different metals combine with different proportions.*

(a.) *There is not, as formerly supposed, an imperceptible progress in the combination of oxygen from the minimum to the maximum; between the definite proportions there are no intermediate stages.*—Those appearances that favor the opposite supposition, probably arise from mixture of various proportions of different oxides, or from the fact that the lowest equivalent of oxygen has not been discovered. There is every reason to believe that the higher proportions are always multiples of the lower, and that the lowest is a divisor of all the higher without a remainder. At least, all the proportions are multiples of a whole number, and divisible by a whole number without a remainder.‡

(b.) *The proportions can therefore be always expressed by numbers.*—Thus, the equivalent or combining power of metallic mercury is expressed by 200 and that of oxygen by 8. Now the black or protoxide of mercury consists of mercury 200 + oxygen 8, 1 proportion, = 208; the red or deutoxide of mercury 200 + oxygen 16, 2 proportions, = 216. Manganese, whose equivalent is 28, has a green oxide, containing metal 28 + oxygen 8, 1 proportion, = 36; a black oxide, with metal 28 + oxygen 16, 2 proportions, = 44.§

(c.) *The metals are various in the number of oxides which they form.*—Some have but one; the greater number have two, and many three; some perhaps more.

8. EFFECT OF WATER IN FORMING OXIDES.

(a.) *Under particular circumstances, water is decomposed by several of the metals*; by some at a common temperature, as potassium,

* Turner. It is obvious that what is usually called white oxide of arsenic, is here regarded as an acid. † Vol. I, p. 189.

‡ This has been already explained under Attraction, Vol. I, p. 160.

§ There is another oxide of manganese, which is supposed to contain metal 28 and oxygen 12, which would indicate $1\frac{1}{2}$ proportion, but perhaps the real protoxide has not yet been discovered.

sodium and iron; by others, only by the aid of a high degree of heat, as antimony and tin; or of the agency of acids, as copper, lead and bismuth; by others it is never decomposed, as mercury, gold, silver and platinum.

(b.) *Water, if capable alone of oxidizing a metal, brings it, at least, to the same degree of oxidizement which it would receive from an acid; sometimes to a higher, never to a lower.**

(c.) *Water dissolves none of the metals, but some of the metallic oxides are soluble in it; this is especially true, since the alkalies and earths are admitted to the class of oxides.*

9. EFFECT OF ACIDS IN FORMING OXIDES AND SALTS.

(a.) *The stronger acids generally act on metals with energy, and it has been long known that when metals are precipitated by alkalies, from their solutions in acids, they are recovered, not in the metallic form, but in that of oxide.*

(b.) *An acid can never dissolve a metal, till it has combined with a certain portion of oxygen.*—This proportion is various in different cases, and in the same metal in different states of solution.

(c.) *The metallic oxides dissolve in acids without effervescence, unless the proportion of oxygen in the oxide is different from that which is required. During the action of sulphuric acid on the red oxide of lead, or the black oxide of manganese, in both of which there is a redundancy of oxygen, there is an effervescence, a portion of oxygen which is not needed for the union being disengaged; but black oxide of iron will dissolve in sulphuric acid without effervescence.*

(d.) *Metals, immersed in those acids which have an attraction for them, are often dissolved with heat and effervescence.*—In all such cases there is a decomposition, either of the acid itself or of the water which it contains, and thus the metal is converted into an oxide, and now becomes soluble in the acid, or in that portion of the acid which remains undecomposed.

(e.) *Gases are often extricated during the solution of metals.*—If the oxygen be derived from the water, then the gas is hydrogen, as in the solution of iron or zinc in the sulphuric or muriatic acids; if from the acid, then the kind of gas depends on the nature of the acid. Thus, nitric oxide gas is liberated during the action of nitric acid on iron, and hydrogen if muriatic acid act on the same metal. Diluted sulphuric acid, with zinc, gives hydrogen; strong sulphuric acid, acting on the same metal, with the aid of heat, produces sulphurous acid gas, which results from the decomposition of the acid. Sometimes the oxygen is obtained from the atmosphere.

* Gay-Lussac, quoted by Henry.

(f.) *The nitric and the nitro-muriatic acids, are those which act most readily on the metals.*—The nitric evolves either nitric oxide, nitrous oxide or nitrogen, and perhaps sometimes a gas analogous to common air; the nitro-muriatic emits either nitric oxide or chlorine, or both. When hydrogen is liberated, as during the action of diluted sulphuric or muriatic acid on zinc or iron, it is easy to prove that the acid was not decomposed, because, by the aid of an alkali, it may all be recovered; with soda, for instance, it will form as much sulphate of soda or Glauber's salt as if no hydrogen had been produced.

(g.) *The quantity of hydrogen gas evolved becomes a measure of the amount of oxygen combined.*—Every 100 cubic inches of hydrogen gas implies the combination of 16.93 grs. of oxygen; different metals act differently in this respect, and it is found that to obtain 1 gr. or 47.2 cubic inches of hydrogen, there must be dissolved 28 grains of iron, 58 of tin, 44 of antimony and 34 of zinc. For every grain of hydrogen liberated, 8 grs. of oxygen have combined with the metal. If the metal is impure, or was previously oxidized in part, there will be less hydrogen evolved, and therefore, upon this principle, a judgment is formed of the amount of real metallic iron in different samples of iron and steel.—*Henry.*

10. NOMENCLATURE OF METALLIC SALTS.—*The same general principles that were explained in connexion with the alkaline salts* are applicable here.*—It is however proper to add that the *nomenclature of the oxides is extended to the salts*; thus *proto* is prefixed to salts containing the first oxide, *deuto* to those containing the second oxide, and so on, ending with *per* for those containing the maximum oxide; thus, we have proto- and per-sulphate of iron. We have also *sub* and *super* salts; the latter however are now more generally expressed by *bis* or *bi*. Dr. Thomson has proposed to use the Greek syllable *dis* or *di*, when, instead of 2 proportions of acid, there are 2 of base; but this has not yet come into general use, and *sub* is still commonly employed.†

11. ACIDS DO NOT COMBINE WITH METALS, BUT WITH THEIR OXIDES.

In principle there is no distinction between alkaline, earthy and metallic salts: it has been already stated, that all salts, with the exception of those of ammonia and of the vegetable bases, consist of acids and metallic oxides, and that, for convenience, the salts

* Vol. I, p. 319.

† Dr. Thomson has also proposed the term *sesqui*, or one and a half, (Latin,) for those cases where there appears to be such a proportion of either of the constituent principles. Perhaps it is admissible as a provisional name, but we may with probability suppose that the lowest combining proportion has not been discovered, and that when it shall be, the fraction will vanish, the lowest term being in fact that which is now regarded as half of a proportion, or, as Dr. Thomson calls it, half an atom.

are, in this work, distributed under the different heads of alkalies, earths and metals; the most important salts of the two first descriptions have been already treated of. The metallic salts will be described under the respective metals, but a few general facts and views may be stated now.

(a.) *The metals are differently oxidized by different acids and under different circumstances.*—With diluted acids and in the cold, the oxidation is generally in a lower degree, but the air may impart more oxygen and raise it to a higher degree.

(b.) *The acids vary in the strength of their attraction, as the degree of oxidation varies.*—In general they attract protoxides most powerfully, and a protoxide of a metal may be soluble in a particular acid when the peroxide is not. Heat and exposure to air often effect such a change that a portion of oxide is precipitated; this often happens with the green sulphate of iron, which, by keeping, passes to the condition of the red sulphate, and lines the bottle with the deposited red or peroxide, whose affinity for the acid is not sufficient to keep it in solution. Hence a peroxide that is insoluble in the nitric or sulphuric acid, may be soluble in the nitrous, sulphurous or muriatic acid, because these acids attract away a portion of oxygen.* The muriatic acid is a good solvent of metallic oxides, but in general it is not so good a solvent of metals. It is often used to detach iron stains from bottles and other glass vessels.

(c.) *In general, acids combine with larger quantities of peroxides than of protoxides, but with a weaker affinity.*—Hence a protoxide may precipitate a peroxide, and the spontaneous precipitation of the latter may be prevented by a large excess of acid. The metallic salts have commonly an excess of acid, and the acrimony of the acids is in them much less blunted than in their combinations with alkalies and earths.

(d.) *The constituents of the metallic salts, like those of the alkalies and earths, are united in definite proportions.*—There is a very considerable diversity of salts of the same metal and the same acid, produced by different proportions of the oxygen in the oxides and of the acid combined with them. The green sulphate of iron has very different properties from the red. The law of multiple proportions prevails, not only between the different proportions of the acids and oxides contained in different salts of the same metal, but there is a relation between the quantity of acid in a given salt and the quantity of oxygen in the oxide with which it is combined, and in any other oxide with which it can combine. This important law was discovered by Gay-Lussac,† and is thus stated.

* Murray.

† *Mémoires d'Arcueil*, II, 159, and *Phil. Mag.* XXXVII, 200.

(e.) *The quantity of acid required in different metallic salts is in direct proportion to the quantity of oxygen in their oxides.** Thus, if two metals combine with quantities of oxygen expressed by 5 and 10 respectively, the quantity of acid required to saturate their oxides will be in the same proportion. This discovery is founded upon the fact that when one metal precipitates another from a solution in an acid, it takes to itself both the oxygen and the acid with which the other was combined, and "whatever quantity of oxygen there may be present, the quantity of acid is always such as to neutralize the oxide and to be neutralized by it. It affords therefore a method of determining the constitution of metallic salts; for if the proportions of oxygen in the oxides, which are their bases, are determined, we may discover by it the quantities of acid; and it may be equally applied to determine the composition of the oxides, for if the quantities of acid be determined, we may infer the quantities of oxygen, the quantity of an oxide saturating the same weight of an acid containing the same quantity of oxygen."†

(f.) *Solubility of metallic salts in water.*—A salt whose oxide is in the maximum state is commonly more soluble in water than when it is in the minimum, for the acid is in the same proportion, and the larger the quantity of acid, in general, the greater is the solubility.‡

DECOMPOSITION OF METALLIC SALTS.

(a.) *Some are decomposed by heat.*—The nitrate of mercury is in this manner converted into red precipitate, or even into running mercury; the sulphate of iron into red oxide or colcothar; nitrate of silver gives metallic silver, either the acid alone, or both the acid and the oxide with which it is combined, being decomposed. Sometimes the acid is expelled without much decomposition, as when sulphuric acid is obtained by distilling sulphate of iron.

(b.) *Some are decomposed by water.*—Thus, nitrate or muriate of bismuth yields most of its acid to water, and the oxide, still perhaps retaining a portion of acid, is thrown down. Nitrate of mercury, made with heat or with a strong acid, allows part of its oxide to precipitate when the solution is diluted with water.

(c.) *The alkalis and alkaline earths are most commonly employed for the decomposition of metallic salts.* The acid is transferred to the alkaline substance, and forms with it a new salt, while the oxide is precipitated. Not unfrequently, a little acid adheres to the oxide, and sometimes a portion of the oxide passes into the new saline combination.

* For a limitation, necessary to render the application of this law perfectly correct, see Henry, 11th ed. Vol. I, p. 514.

† Murray, Vol. II, p. 136.

‡ Among the alkaline salts there are some exceptions to this law; cream of tartar or bi-tartrate of potassa is much less soluble than when the excess of acid is saturated with alkali, forming soluble tartar.

Occasionally also, a portion of the oxide is dissolved by the alkali. This is the case, particularly with ammonia, which forms with the oxides *ammoniuirets*, and Dr. Henry states that it dissolves fifteen oxides, or *hydrated oxides*,* viz. "oxide of zinc; deutoxide of arsenic; both oxides of copper; oxide of silver; tritoxide, and tetroxide of antimony; oxide of tellurium; protoxides of nickel, cobalt and iron; peroxide of tin; deutoxide of mercury; and deutoxides of gold and platinum."

Heat, by causing a combination between the oxygen of the oxide, and the hydrogen of the ammonia, decomposes the ammoniuirets, and sometimes, as in those of silver and gold, with explosion, to which effect the liberation of nitrogen contributes.

When a carbonate of an alkali is used to decompose a metallic solution, the oxide is precipitated in combination with carbonic acid, forming a carbonate, which, by the addition of an acid, is redissolved, with effervescence, while the oxide alone would have been redissolved quietly.

(d.) *Alkalies have in general, little action on the metals; but their solutions oxidize the metals.*†

(e.) *It has been already remarked, that metallic oxides are often easily dissolved in alkalies.* Contrary to what happens with acids, the affinity is stronger the more highly the metal is oxidized. The combination is usually brought about in the humid way, but some of these compounds are vitrifiable.

(f.) *By inflammable substances, especially when aided by light.* Thus, phosphorus, hydrogen and charcoal precipitate silver from nitrate of silver, and hydrogen reduces muriate of bismuth, and acetate and nitrate of lead. More instances will be mentioned in giving the history of the particular metals.

(g.) **METALLIC SALTS ARE OFTEN DECOMPOSED BY OTHER METALS.**

The metals have different degrees of attraction for the same acid, and for the oxygen of the oxide, and hence arise metallic precipitations.

Thus, silver, mercury, copper and lead are precipitated from the nitric acid, by iron or zinc—lead precipitates mercury, and mercury silver. Iron is more extensively employed for metallic precipitations than any other metal, and after it, iron, copper and zinc. The effect is supposed to depend principally upon the affinity of oxygen for the

* Vol. I, p. 518, 11th Ed.

† Alkaline solutions sometimes change the color of metallic oxides, by taking away a portion of oxygen. The red oxide of iron is soon converted into the black, by a solution of potash. In the case of ammonia, this is not perhaps surprising, as it contains hydrogen, which attracts oxygen powerfully, and we now know that the fixed alkalies do also attract oxygen, and can become more highly oxidized.

metal introduced ; but the acids have their share in producing the effect, and the metals themselves operate also, to a degree, by their affinity for each other ; for metallic precipitation takes place most easily where these affinities are known to exist, and the precipitated metal generally retains a little of that which was used to precipitate it. Some beautiful effects depend upon metallic precipitation ; as when nitrate of silver is decomposed by mercury, or acetate or nitrate of lead by zinc ; there is an elegant arborescence of the precipitated metal in brilliant crystalline shoots, or leaves, which grow and change from day to day, until the effect has obtained its maximum. It is now known to depend, (after the very first precipitation which is purely chemical,) upon galvanic laws, as the two metals and the saline fluid form a regular galvanic series, and will be more fully explained under galvanism.* Metallic precipitation is employed largely in some of the arts ; in the mints, silver is precipitated from the nitric solution by copper.

12. *Metallic oxides combine with water forming hydrates or hydrated oxides.*

The term was not perhaps happily chosen, as it may seem to imply some connexion with hydrogen, and the termination is also that which is appropriated to the salts.

The hydrates of the metallic oxides are obtained by precipitation, usually from the muriate, nitrate, or sulphate of the metal by means of an aqueous solution of either of the alkalies ; the precipitate, after being washed, is carefully dried by a very mild heat. The hydrated oxides are generally more soluble in acids than the oxides without the water.† Some of the hydrates are found native, such is the brown oxide of iron.

The hydrates of the fixed alkalies, and of the earths strontia and baryta, retain their water with so much force, that a red heat does not separate it, and the intervention of another substance operating by its affinity, is necessary. The proper metallic oxides are, with few exceptions, nearly or quite insoluble in water.

The deutoxide of arsenic, now generally called by chemists, arsenious acid, and the oxide of osmium are soluble in water ; also the oxide of molybdenum, deutoxide of mercury, and trit- and tetroxide of antimony, in a degree not exceeding one part in a thousand.—*H.*

The alkalies are largely, and several of the earths considerably soluble.

* For a curious law deduced by Lavoisier, respecting the proportion of the precipitating and precipitated metal, and of the oxygen which they respectively require, see Henry, Vol. I, p. 486.

† Berzelius states that they are definite compounds in which the oxygen of the water is equal to that of the oxide.

13. *The earths have little action on the metals*, but by fusion they readily unite with their oxides, and thus the colored glasses are formed, as already stated under the history of glass.

II. CHLORINE—*its action on metals*. In giving the history of chlorine, some leading facts relating to this subject were anticipated. It remains to present them in relation to the metals, in a concise and connected manner.

1. *Chlorine combines with all the metals*, and it acts upon many of them with energy.

(a.) *It burns those that readily combine with oxygen*. Powdered arsenic, bismuth, or antimony, or the sulphuret of the latter, thrown into the warm gas, burns with flame.

Several other metals exhibit similar phenomena. Generally, the metals are introduced in such a form as to present an extended surface, as in leaves, or in powder; about 1 grain of the metal, to 1 cubic inch of the gas, not colder than 70°.

The action of each metal upon chlorine will be mentioned under the history of the particular metals.

(b.) *The compounds formed are called chlorides*.

(c.) *The attraction of chlorine for the metals is stronger than that of oxygen*. Brought into contact at ignition, with the fixed alkalies and alkaline earths, as by passing the chlorine gas over them in a porcelain tube, it expels their oxygen, and combines with the metal, and no degree of heat has been found sufficient to separate the chlorine from such a combination.

(d.) *Most of the metallic oxides, (usually so called,) are affected in the same manner by the same treatment*; and some of them combine with chlorine, and give up their oxygen even below ignition.

(e.) *Various metals, on being heated in muriatic acid gas, absorb its chlorine, liberate its hydrogen, and thus form chlorides*.

(f.) *It results, that the action of chlorine and muriatic acid on metals, and on metallic oxides, with an appropriate degree of heat, produces the same compounds, namely, chlorides*.

2. CHLORIDES—MURIATES.

We have already presented a view of the connexion between these productions, so closely allied, and still so different.

(a.) THE CHLORIDES.—PROPERTIES, *solid, excepting two, the bi-chlorides of tin and of arsenic, which are fluid; fusible, and crystallize on cooling, sometimes with regularity*. Some are volatile, as those of tin, arsenic, antimony, and mercury, and are sublimed without change; their appearance is like that of saline bodies; most of them are soluble in water, but the chloride of silver, (the muriate,) and the proto-chloride of mercury, (calomel,) are insoluble.

(b.) *In general, they are not decomposable by heat.* The chlorides of gold and platinum are exceptions, as they are reduced by heat.*

(c.) *Hydrogen gas, with ignition, decomposes the chlorides*, forming muriatic acid gas, and liberating the metal; they are not decomposed by charcoal, unless it is moist.

(d.) *Muriates are formed from chlorides*, as has been already stated in the history of chlorine.

Diluted muriatic acid, acting on metals that decompose water, forms muriates, as in the case of iron; or with an oxide of the metal, this acid produces the same result.

(e.) *In some cases, crystallization, it is said, changes the muriate into a chloride*, as with potassa and soda, while in other instances, the muriate crystallizes as such; this has been already stated with respect to baryta, strontia, lime, magnesia, and alumina; and the oxides of copper, and manganese are added; all these are supposed to consist of definite proportions of muriatic acid, oxide, and water. If heated, the crystallized muriate first loses its water of crystallization, and then the oxygen of the oxide, and the hydrogen of the muriatic acid unite and pass off in watery vapor, while the chlorine and metal remain in union to form the chloride. On being dissolved in water, the reverse changes are supposed to happen, from the decomposition of that fluid.

(f.) *Insoluble chlorides are supposed to remain permanently the same.*—Some admit that the chlorides are soluble in water, without any change, and especially that those metals which have little attraction for oxygen, when combined with chlorine, retain whether moist or dry, the condition of chloride; such are gold, platinum, silver and mercury. Those chlorides whose metals have a moderate attraction for oxygen may, when dissolved in water, be regarded perhaps with equal probability, as muriates or chlorides; such are the chlorides of copper, lead, nickel, and cobalt.†

3. CHLORINE UNITES ALSO WITH METALLIC OXIDES.

Several of the most important of these compounds have been already treated of.

(a.) *They are formed, and can exist only at low temperatures, and are very liable to decomposition*, passing into new forms of existence, as chlorates, chlorides, and muriates. We are acquainted with at least the chlorides of the fixed alkalis, and alkaline earths; those of the oxides of zinc, copper, and iron have also been formed.‡

The most useful of these compounds are the chlorides of potassa and soda, which can exist only in dilute solution, and in the cold; and the chloride of lime, which is formed with the dry hydrate as

* Turner.

† Murray.

‡ Ann. de Chim. et de Phys. T. XVII.

well as with the wet, but it is gradually decomposed by keeping; even the carbonic acid of the atmosphere separates the chlorine.

The principles of the nomenclature of the salts are extended also to the chlorides; thus we have chloride, proto-chloride, deuto-chloride, bi-chloride, &c. terms which need no explanation. The student will of course distinguish between a chloride, which is a compound of chlorine and a base; a chlorate, which is a compound of chloric acid, (chlorine and oxygen,) and the oxide of a base; and a muriate, which is composed of muriatic acid (chlorine and hydrogen,) and the oxide of a base. Thus we have chloride of potassium, and chlorate and muriate of potassa, &c.* Hitherto, chlorine has not been found to combine in more than two proportions with any one metallic base.†

III. IODINE‡—its relations to the metals.

1. *Iodine has a strong affinity for metals, and unites with them all.* Sometimes mere contact is sufficient, as with potassium; at other times, a moderate heat is applied, as with mercury, and at others the union is formed indirectly, from the compounds of the two substances. Some of the compounds of iodine with metals have fine colors.

These compounds are called *iodides*, in analogy with oxides and chlorides.

2. *Chlorine separates iodine from all the metals;* if it be passed in gas over a heated metallic iodide, the iodine is evolved.

3. *In general, oxygen gas passed at ignition, over metallic iodides, separates the iodine and forms oxides;* thus it appears that the affinity of iodine for the metals is inferior both to that of chlorine and oxygen.

4. *But some of the metallic oxides are decomposed at ignition by vapor of iodine.* The instances hitherto known are those of potassa, soda, protoxide of lead, and oxide of bismuth.§

5. *Vapor of iodine passed over red hot lime, baryta, and strontia, does not decompose these oxides, but combines with them to form an iodide of the oxide, being in this respect unlike chlorine, which, in the same circumstances, forms a chloride of the metal.*

No other iodide of an oxide is formed in the same way, and any other iodides of oxides, of which there are very few, have their principles united by very feeble affinities, and are decomposed at ignition. It has been already stated, that iodine, added to solutions of alkalies, or alkaline earths, forms iodates, and hydriodates, by the

* See pp. 45, 46.

† There are three chlorides of carbon, pp. 21, 22.

‡ For the discovery of iodine in the Saratoga mineral waters, see Am. Jour. Vol. XVI, p. 216, Dr. Usher; p. 242, Dr. Steel.

§ Turner.

decomposition of water, just as happens with chlorine, which, in the same circumstances, forms chlorates and muriates.

IV. BROMINE ;* *its relation to the metals.*

A general view of this relation has been given under bromine,† and some facts may be added under the particular metals. The compounds are called *bromides*, and by some, bromurets, but the former term is preferable, as corresponding better with oxides, chlorides, and iodides. The bromides are formed either by the direct action of bromine upon the metals, or upon their oxides, the process being aided by heat ; or by the same agent, the hydro-bromates are turned into bromides, by a theory already explained.

I have observed that the action of potassium upon bromine, as stated by Mr. Balard, is extremely violent, and attended not only with light and heat, but with explosion ; it is sufficient for this purpose, to throw a small piece of potassium into a wine glass containing a few drops of bromine.

V. SIMPLE COMBUSTIBLES.

Most of the metals unite with some of the simple combustibles, but not with all. Nitrogen unites with none of them.

1. PHOSPHORUS.—Pelletier first combined phosphorus with metals.‡

(a.) *It may be done by plunging, with a long forceps, pieces of phosphorus into the bottom of a crucible containing the melted metal ; but most of the phosphorus is dissipated in flame.*

(b.) *It is better effected by mixing the vitreous phosphoric acid with charcoal and the metals, and by exposing them to heat, when at the moment of the liberation of the phosphorus, by aid of the carbon, from its union with the oxygen, the phosphorus and the metal unite ; and the same object is effected by heating the phosphates and the metals with charcoal. Some metals which attract oxygen powerfully, decompose the phosphoric acid without charcoal and form a phosphuret.*

(c.) *Phosphuretted hydrogen passed over metallic oxides, ignited in a porcelain tube, forms phosphurets ; the phosphorus uniting to the metal and the oxygen of the oxide to the hydrogen of the gas, to form water.*

(d.) *The metallic phosphurets are brittle, dark colored bodies, retaining something of the metallic lustre ; but being hitherto useless, their properties have been little investigated, and for the little we know of them we are indebted almost exclusively to the researches of Pelletier.§*

* Prof. Torrey informs me that a drop of Bromine produced a blister on his hand. Bromine has been introduced into medicine under the form of per bromide of mercury.

† See p. 89.

‡ Ann. de Ch. Tom. I and XIII.

§ Ann. de Ch. Tom. XII and XIV, and Rose in Ann. de Ch. et de Ph. Feb. and Aug. 1827.—The phosphurets of the alkalis and earths have been already described under the history of those bodies.

2. HYDROGEN.

(a.) *In general, forms no union with the metals.*—A minute portion seems to go over with the hydrogen gas extricated during the solution of some of the metals in acids; as is said to be the case with zinc, and in a small degree, with iron.

(b.) *The most decided compounds of hydrogen with metals are found in the cases of arsenic, tellurium and potassium, all of which are in the gaseous form;* but there is also a compound of tellurium and of arsenic in the solid form; that of tellurium appears when, in the galvanic circuit this metal is employed at the negative pole, in the decomposition of water; the hydrogen does not escape as a gas, but combines with the metal and falls in the form of a brown powder. That of arsenic is obtained by decomposing water by an alloy of potassium and arsenic; it appears in chesnut brown flocks.

3. CARBON.

(a.) *Carbon combines with only one* of the metals, namely, iron; forming steel and cast iron;* both of which are carburets of iron, more or less impure; the method of forming steel will be mentioned under the article iron.

(b.) *The native carburet of iron exists in abundance in the form of plumbago,* commonly called black lead, but as the iron appears to be very variable in the proportion, it is possible it may be like the silica and other earths, adventitious.

4. SULPHUR.

(a.) *Exists natively, combined with many of the metals, forming some of the most common ores.*

(b.) *Sulphurets are formed by heating the metal, in filings, leaves or sheets, in contact with sulphur;* the union is sometimes attended by a bright light and great heat, resembling combustion.† This happens in vacuo or in any gas, and appears to be dependent exclusively on the reaction of the bodies themselves. It is not therefore a combustion in the usual sense of that word, although it is now common to call every case of energetic chemical union, with evolution of heat and light, a combustion.‡ Filings of iron 45, or copper 40 parts, and 15 of sulphur slowly melted in a glass tube or flask, (one point being heated a little more than the rest,) combine with bril-

* It is said by some to combine with zinc.—*Murray's Elcm.*

† Probably the emergence of heat and light is dependent upon the same general causes that evolve them in combustion, of which a change of capacity has usually been regarded the chief; it affords however only an imperfect explanation in some cases, and is entirely inapplicable in others.

‡ Were this a combustion, as the word was formerly used, the iron would be found oxidized and the sulphur acidified; but the compound, by the aid of an acid, decomposes water, and sulphur rises dissolved in the hydrogen, both of which facts are inconsistent with a previous combustion; and even the bi-sulphuret is still entirely combustible. See remarks, p. 96.

liant ignition.* A similar appearance is exhibited during the combination of sulphur with lead, bismuth, sodium and potassium.

(c.) *Gold, tin and zinc do not combine with sulphur by fusion*, although they are readily dissolved by the alkaline sulphurets. The attraction of the metals for sulphur is different, and they may be even made to separate each other from it, in a certain order.† Thus, sulphuret of mercury is decomposed by ignition with iron filings, which absorb the sulphur, while the metal distils over. Sulphuret of antimony is decomposed in a similar manner.

(d.) *Metallic sulphurets are obtained also by heating sulphur with the oxides of metals*, whose oxygen flies away with a part of the sulphur in the form of acid, while another portion of sulphur combines with the metal.‡ This is supposed to happen when sulphur is heated with potassa, so that the compound is a sulphuret, not of potassa, but of potassium.‡

(e.) *A similar result is obtained, when sulphates are decomposed by ignition with inflammable matter*, particularly with hydrogen, passed over the pulverized or melted sulphate in a red hot tube, and by charcoal heated with the sulphate in a similar manner in a crucible.

It is now fully ascertained that the resulting compound is not a sulphuret of the oxide, but a sulphuret of the metallic base.§ This enables us to understand why it so readily decomposes water and forms sulphuretted hydrogen, especially when aided by an acid; the proto-sulphuret is chiefly active in this way, the bi-sulphuret being much more stable in its composition.

PROPERTIES OF SULPHURETS OF METALS.

(a.) *Lustre often sub-metallic; those of antimony, lead and iron, have commonly a high lustre; opaque, brittle, more fusible than the metal which they contain, generally fixed in the fire, but those of arsenic and mercury (orpiment and cinnabar,) are very volatile.* Commonly not decomposed by heat, at least, when they contain only one proportion of sulphur, but if there is an additional proportion, that part is more easily expelled.

* Gases, amounting to 9 or 10 times the volume of the materials, and consisting of sulphuretted hydrogen and sulphurous acid, are evolved.—Phil. Trans. 1803, note to Sir H. Davy's paper on alkalis. Some moisture in the sulphur and a little oxidation of the metal, are thought to account for the fact.—Ann. de Chim. Feb. 1807. In the case cited by Sir H. Davy copper and sulphur were employed.

† Black, Vol. II, p. 413.

‡ And perhaps also a part of the acid combines with a part of the oxide of the base.

§ See Dr. Henry and Dr. Turner, also Ann. de Chim. et de Phys. Vol. VI, XX, and XXII.

The different proportions are indicated by a nomenclature formed upon the same principles that have been explained. Thus we have sulphuret or proto-sulphuret—sub-sulphuret and bi-sulphuret.

(b.) *The higher proportions of sulphur are multiples of the lowest.*—Thus the magnetic pyrites or proto-sulphuret of iron, is composed of iron 100, sulphur $58\frac{1}{2}$, and the bi-sulphuret or iron pyrites of 100 iron + 117 sulphur, the sulphur in the second instance being double of that in the first.

(c.) *The sulphurets are decomposed, if heat and air operate upon them at the same time,* for the oxygen of the air attracts the sulphur to form acid, and the metal to form an oxide. It is upon this principle that the sulphurets are roasted in metallurgic operations, the metal being left in the state of oxide.

(d.) *But if the sulphuret retains its sulphur with sufficient power, it will be acidified while the metal is oxidized,* and thus a sulphate of the oxide will be formed. This is the foundation of the manufacture of copperas.* It has been proved by Berzelius, that the quantity of sulphur existing in a metallic sulphate and sulphuret of the same metal is the same.

SULPHURETS OF OXIDES.

(a.) *The former opinion respecting the nature of the sulphurets of the fixed alkalis and earths† has been modified,* and on p. 352, Vol. I, it has been stated under what circumstances they are to be regarded as compounds of sulphur and oxides, and when of sulphur and metals.

(b.) *In general, sulphur does not unite with the common metallic oxides;* but it is believed that mercury, zinc, and manganese,‡ are exceptions, as sulphur unites not with the metals but with their oxides. The muriatic and sulphuric acids evolve sulphuretted hydrogen from sulphuretted oxides, provided they are in the condition of protoxides; if of peroxides, the latter dissolve without emission of gas and let go the sulphur.

(c.) *Sulphuretted hydrogen and hydro-sulphurets decompose the metallic solutions,§ and form sulphurets or hydro-sulphurets.*

* For instance, as carried on at Stafford, Vermont, twelve miles west of Dartmouth College; the ore there is the magnetic pyrites or native proto-sulphuret.

† Gay-Lussac, (quoted on p. 352, Vol. I,) says, that if a metallic oxide is heated below redness with sulphur, the product is a sulphuretted oxide.

‡ Doubts are entertained whether there are any true sulphurets of oxides even of these metals. See Henry, 11th Ed. Vol. I, p. 531, note.

§ All the metallic salts are decomposed by the hydro-sulphuret of ammonia or potassa, but the solutions of manganese, iron, nickel and cobalt, are not decomposed by sulphuretted hydrogen, unless they are dissolved in weak acids, as the acetic, tartaric, and oxalic, and the ammoniurets of these metals are entirely decomposed by sulphuretted hydrogen.

(d.) *Sulphuretted hydrogen tarnishes most of the metals*; it unites with mercury and silver,* but in general it combines with metallic oxides rather than with metals.

(e.) *It is an excellent test of the presence of metals in solution, and the color of the precipitate indicates what metal is present.*—In the course of some time, these precipitates are often spontaneously decomposed; the oxygen of the oxide unites with the hydrogen of the sulphuretted hydrogen and forms water, while the sulphur combines with the metal.

(f.) *By using hydrogenized sulphurets of the alkalies, we may obtain hydrogenized sulphurets of the metals.*—Some metals that do not unite directly with sulphur, can be made to combine with it by being heated with an alkaline sulphuret, and then they become even soluble in water, but neither the nature of the action nor the condition of the metal when dissolved, is very well understood.—*Murray.*

Other particulars relating to the action of sulphur and its compounds upon the metals and their compounds, will be mentioned in giving the history of the individual metals.

VI. SELENIUM.

Selenium readily unites with the metals at a high temperature, as the hydro-selenic acid does with the oxides of the metals in metallic solutions, but the metallic seleniurets have a very close resemblance to the metallic sulphurets, and no particular instruction would be gained by going over their history.

VII. THE SALTS.

(a.) *The saline bodies have in general no very marked action upon the metals; the chief exceptions are in the case of the sulphates, nitrates, chlorates and iodates;*† all these, when aided by heat, and the three last frequently by pressure alone, act upon metals that have a strong attraction for oxygen, and

(b.) *Their action is attributable to the oxygen contained in their respective acids,* which are of course decomposed, and give products containing their principles or portions of them, combined in new modes or in new proportions.

(c.) *The sulphates are commonly reduced to sulphurets* without any remarkable phenomenon, the transfer of oxygen taking place quietly.

(d.) *The nitrates and the chlorates act with much energy,* frequently inflaming the metals, especially if finely pulverized, and introduced into the salts when hot; with the chlorates, many of the metals detonate simply by percussion.

* Henry; in such cases perhaps it is rather the sulphur of the gas that unites with the metal.

† And probably bromates.

VIII. ALLOYS.

1. *Most of the metals unite with each other and form a class of bodies called alloys.*—They furnish some of the most useful materials for the wants of mankind. Thus, brass is a compound of zinc and copper—bell metal, of copper and tin—pewter, of tin and lead, sometimes with the addition of copper and bismuth or zinc.

(a.) *The alloys are generally formed by fusion, but mercury dissolves many of the metals by contact merely; especially if aided by rubbing in a mortar.*

(b.) *The compounds of mercury with the other metals are called amalgams.**—Thus the amalgam of zinc and mercury is used for electrical machines.

PROPERTIES OF ALLOYS.

1. PHYSICAL.

(a.) *The specific gravity of the compounds of the metals is almost never the mean of the two—usually it is greater, but sometimes less.*

(b.) *Sometimes the compound is heavier than the heaviest of the ingredients.*—An amalgam of silver sinks in mercury.

(c.) *Sometimes the sp. gr. is diminished*—116 parts of tin and 104 of lead should give a compound of sp. gr. 9.321, but the real sp. gr. of the alloy is only 8.817.†

The sp. gr. of tin is 7.363, that of brass 8.006, but that of a compound of 2 parts of brass and 1 of tin is 8.916, while the proportion of the whole composition, since in it there are three metals united, should have been 7.793.

(d.) *Soldering is founded on the mutual attraction of metals; for gold, the solder is a mixture of gold and silver—for copper, brass‡—for brass, the same composition, with a greater proportion of zinc—for lead or tin, a mixture of both or pewter.*

(e.) *The cohesion of the alloy is also generally greater than in the proportion of that of the ingredients*—12 of lead and 1 of zinc are twice as coherent as the zinc.§

(f.) *When metals, whose specific gravity is widely different, are melted together, especially if their affinity is weak, they will not always unite equally.*—Mr. Hatchett found that when a bar composed of copper and other metals and gold was cast vertically, there was more gold at the bottom than at the top.

(g.) *Some metals appear to have little or no affinity for other metals, as iron and lead, or iron and mercury, and yet iron and mercury can be united by circuitous processes.*

* From *ama* and *yapere*.

† Black, II, 416.

‡ Thom. First Prin. I, 29.

§ Vid Hatchett, in Nich. Jour.

(h.) *Alloys retain the metallic properties.*—They are opaque, have the metallic lustre, and are good conductors of electricity and of heat.

(i.) *Still their properties are often different from those of the parent substances.*—Ductility and malleability are generally impaired; half a grain of lead destroyed the tenacity of an ounce of gold, and an alloy of platinum, copper and zinc, although very ductile and malleable, became brittle by the addition of half a grain of iron to 4 oz. of the alloy,* and gold becomes brittle by being kept in the vicinity of melted lead, probably absorbing some of its vapor.

(j.) *Alloys of brittle metals are always brittle, and a brittle metal, especially if in excess, generally imparts brittleness to a ductile metal,* and two ductile metals sometimes become brittle by uniting.

(k.) *The hardness is altered and sometimes increased,* as is seen in the gold and silver coin which is hardened by copper, and in type metal, which is hardened by antimony.

A little gold renders iron, (it is said,) harder than steel.

(l.) *Color is changed.*—A little palladium debases the color of gold, and arsenic generally renders the metals white with which it combines. In color, brass is not like either zinc or copper.

(m.) *The fusibility is altered.*—Platinum, infusible in the best wind furnaces, is easily melted by the addition of arsenic.

(n.) *The volatility is also increased.*—A little gold sometimes distils over during the heating of the amalgam of that metal.

2. CHEMICAL PROPERTIES.

(a.) *In general, metals, in consequence of being alloyed, are more prone to unite with oxygen;* partly from a diminution of cohesion, and partly from a galvanic effect. Alloys of metals are always more easily oxidized, and have a stronger taste than either of the metals separately. It is said that an amalgam of tin inflames at the moment when the metals unite, and that amalgams of gold and silver are oxidized by agitation with the air. Mr. Faraday observed that an alloy of steel with $\frac{1}{4}$ of platinum, dissolved with effervescence in dilute sulphuric acid so weak, that it hardly acted on common steel. He supposed the steel to be rendered positive by the presence of the platinum. If gold is alloyed with a small proportion of silver, the latter is rendered insoluble in nitric acid, but by carrying the proportion of silver to one fourth of the whole, it is dissolved, as in the process of quartation.

Gilding, silvering, tinning, and soldering, depend on mutual affinities between the metals.

(b.) *Metals probably combine in definite proportions.*—The contrary appears at first view to be the fact, for it would seem that gold

* Eng. Journal of Science, III, 119.

and quicksilver, and gold and copper, unite in every proportion. But *we are acquainted with several cases where the combination of metals is in definite proportions, and therefore we may presume that metallic combinations are generally of this character.* The *arbor Dianæ* and the native amalgam of mercury and silver* are in definite proportions, and potassium gives two such crystallized compounds, the one of which contains twice as much potassium as the other. The fluid amalgams of silver contain a solid amalgam, floating in the fluid, and this is probably the definite compound; it can be strained out through leather.

VIII. METALS SIMPLE SUBSTANCES.

As, during the oxidation of metals, their weight is increased, by that of the oxygen added; as the latter can, in every case, be disengaged again, either by heat alone, or by the aid of charcoal or hydrogen, when the gas or vapor produced is found to be precisely equal in weight to the combustible, and the additional weight acquired by the metal during its oxidation; and, as the metal, by reduction, is recovered in its original condition without loss, *it is rendered in the highest degree probable, although, like other negative facts, it can never be demonstrated, that the metals are simple substances.*

It has been more than once mentioned, that *the object of alchemy was to form the precious metals; an attempt which of course proceeded upon the presumption that they are compound.* This presumption, so far from involving any absurdity, is even countenanced by the high equivalent numbers of many of the metals, and of the noble metals in particular. Still, chemistry affords at present, no ground for believing that the metals are compound; should they, in the progress of discovery, prove to be so, it would produce great changes in the foundations of the science, and perhaps also in the superstructure.

NATURAL HISTORY OF THE METALS.

This is the province of mineralogy and geology, and will be mentioned, on the present occasion, no farther than to state the chemical condition of the ores. Metals are found either in the metallic state or combined with some foreign substance, which is called a mineralizer. The principal mineralizers are oxygen, combustibles and acids; among these, oxygen is the most important; among combustibles, sulphur is the chief; and arsenic, from the peculiar effects which it produces, may be regarded as a distinct mineralizer.

The metals, in their natural state, are called ores, and they may all be included under the following descriptions.

* Mercury 64, silver 36—Klaproth; nearly in the proportion of 200, 1 equivalent of mercury, to 110, 1 equivalent of silver.

1. Native metals and alloys.
2. Oxides.
3. Sulphurets, carburets, phosphurets, &c.
4. Salts.*

METALS.

1. REMARKS.

(a.) It has been already observed, that *the class of metals has been very much increased by the researches of modern chemistry*, and that *the ancients distinctly knew only seven*, namely, *gold, silver, copper, mercury, iron, tin and lead*; besides perhaps a few of the ores and combinations of some of the other metals.

(b.) *Excluding the bases of the fixed alkalies and earths, which have been already described or mentioned, the number of remaining metals is twenty eight*; nearly the whole of which are well distinguished from all other bodies. Most of those of modern discovery have been, as yet, applied to little use; but, potassium and sodium have rendered signal service to scientific chemistry; and chromium has given splendid and enduring colors to the arts; nor can we say, that those metals which now appear of little importance, may not hereafter prove highly useful. The new metals, including those of the fixed alkalies and earths, have greatly enlarged our knowledge; and the whole elementary constitution of matter has thus attained the most unexpected simplicity; for, metals and the other combustibles and the agents that burn them, now include the whole of the ponderable elements.

2. CLASSIFICATIONS OF THE METALS, according to their properties, are frequently given by authors; they *are not without utility*, as means of aiding the memory in recollecting some prominent facts, such as their relation to oxygen and (what depends on this) their power of decomposing water.

Thénard, for instance, on this principle, *divides the metals into six sections*; but divisions so numerous are troublesome to remember, and are not well appreciated by the learner. I prefer therefore, with *Dr. Henry*, the older and simpler division, founded also upon the same basis. The metals may all be comprehended in two classes.

I. *Those whose oxides are not reducible by heat alone*, but require the aid of a combustible body.

II. *Those whose oxides are reducible by heat alone*.—More than three fourths of all the metals are included within the first class, and, as already stated, only nine in the latter; namely, quicksilver, silver, nickel, gold, platinum, and its four attendant metals, palladium, rhodium, iridium and osmium.

* A discourse on mines and mining, which was appended to my editions of *Henry's Chemistry*, was revised for the present work, but, for want of room, will probably be excluded from the appendix.

By adopting this arrangement, we shall pass, by a gradual transition, from those metals which are in general, less known, less important and less interesting, to those whose character is opposite in these particulars.

We again present a catalogue of the metals, founded, as regards its order, upon this view; including the metals of the fixed alkalies and earths with the rest, and all of them in the order in which they have been or will be described.

1. Potassium, see Vol. I, p. 243.	21. Manganese.
2. Sodium, " " 253.	22. Arsenic.
3. Lithium, " " 258.	23. Cobalt.
4. Calcium, " " 264.	24. Antimony.
5. Barium, " " 268.	25. Zinc.
6. Strontium, " " 271.	26. Cadmium.
7. Magnesium, " " 274.	27. Bismuth.
8. Aluminium, " " 293.	28. Tin.
9. Glucinium, " " 299.	29. Lead.
10. Zirconium, " " 297.	30. Iron.
11. Yttrium, " " 301.	31. Copper.
12. Thorium, " " 301.	32. Nickel.
13. Cerium.	33. Mercury.
14. Columbium.	34. Silver.
15. Molybdenum.	35. Gold.
16. Chromium.	36. Platinum.
17. Titanium.	37. Palladium.
18. Tellurium.	38. Rhodium.
19. Uranium.	39. Iridium.
20. Tungsten.	40. Osmium.

Remark.—It being yet doubtful whether the base of silica is a metal, it is omitted in this catalogue, and retained among the combustibles.

Although the first twelve of the metals have been already described or mentioned under the alkalies and earths; some additional facts will be inserted here, under their proper heads.

We shall then proceed to a consideration of each of the remaining twenty eight metals, and of their relation to the other bodies and to each other, pursuing, generally, the order in which the simple bodies have been considered; with perhaps occasional variations.

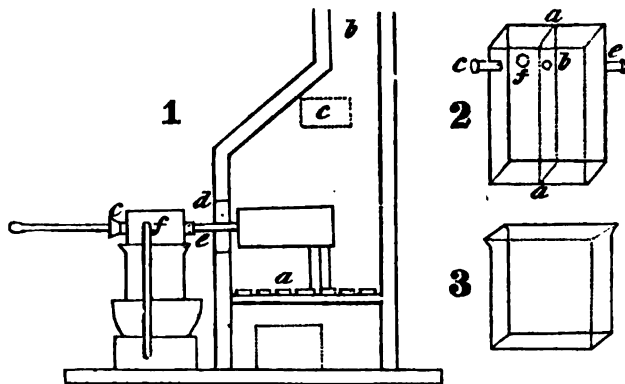
In connexion with each head, we may briefly mention the ores, and the extraction and uses of the metals.

1. POTASSIUM.

Additional facts respecting the preparation of this metal.—The processes of Professor Brunner, and of M. Wöhler, of Berlin, were mentioned Vol. I, p. 246. The following more particular statement is abstracted or copied from the 11th edition of Dr. Henry's Chemistry,

(a.) *Process of Prof. Brunner.*—The spheroidal iron bottle is connected with the receiver by a gun-barrel, bent into this form. (N) After the retort is charged, it is placed in the furnace, so that the longer leg of the gun-barrel may pass out at the bottom, or in front, in a direction nearly perpendicular, the bent part itself, wound round with iron wire, remaining in the furnace. The receiver is a cylindrical copper vessel, with an orifice at top for the gun-barrel, and one at the side for the escape of the gases. In decomposing the potassa, charcoal is a powerful auxiliary to the iron. The retort being previously cleaned, dried and heated, was charged with 4 oz. of solid caustic potassa, mixed in small pieces, with 6 oz. of broken iron turnings, and 1 oz. of charcoal powder. The fire was gradually raised, and in half an hour, the green vapors of potassium appeared in a glass tube attached to the end of the gun-barrel, and the receiver was now applied, so that the end of the gun-barrel dipped into naphtha. A great quantity of gas was evolved, which frequently flashed spontaneously, with a violet flame,* and white fumes; in 25 minutes from the application of the receiver, the gas diminished, and soon ceased; 150† grains of potassium were the result.

2. *Process of M. Wöhler.*

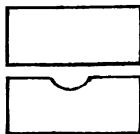


"The furnace, No. 1, is about four feet high, and nearly two feet square. The bars of the grate stand a little above the level of the floor, and rest upon a bearer, by the removal of which they may be made to fall down together, and thus the fire may be removed at any

* In the process of Gay-Lussac and Thénard, by the gun barrel, I have often witnessed this splendid combustion, which is one of the most beautiful that chemistry affords.

† I have sometimes obtained that quantity, by the gun barrel, from 2 or 3 oz. of caustic potash.

required moment. The draught of air is from a room below. About the middle of the front of the furnace at *d* is a square hole, capable of containing two bricks, and within the body of the furnace, a little below the above mentioned opening, are two bars of iron, placed horizontally, and dividing the space within the furnace equally. Two other bars cross these, and are tied to them by iron wire, in such a manner as to make a firmer seat for the retort than by a single brick as shown in the cut. The retort is an iron bottle of the kind used for containing quicksilver. A square piece of stone is hollowed to receive the tube (a piece of gun barrel, about a foot long,) screwed into the retort; and a brick is placed over the stone, so as to fill up the square opening mentioned above. The whole is then covered with luting, and the iron bottle, with its contents, is placed in the furnace, as represented in the figure, in which *a* is the grate; *b*, the flue; *d*, the square opening through which the apparatus is introduced, and which is afterwards closed and luted over; *c*, the opening for introducing fuel; but, in the instance witnessed by Dr. Fleming, the fuel (wood charcoal) was supplied more conveniently through a hole at the top, which had a lid furnished with hinges. The charcoal fire was at least four inches above the top of the retort, and the body of fire perhaps eight inches below it.



"The receiver (figs. 2 and 3) is the invention of M. Berzelius. It is a foot high, 6 inches long, about 4 inches wide, and is best when made of strong sheet copper. It is composed of two pieces; No. 2 is of such a size as to pass into No. 3 with some degree of friction. It may be either right angled or elliptical. The part No. 2 is divided into two equal parts by a diaphragm *aa*, pierced by a small hole *b*, on the same line with the tubulures *c* and *e*; and on one of its larger faces is a third tubulure *f*, by which the gases are allowed to escape. If the receiver be oval, the diaphragm may be placed in its greater diameter. Naphtha is put into the receiver, No. 3, till about half full, and the receiver is then placed in a wooden trough containing ice water, kept cold by fresh additions of ice. Lastly, the tubulure *e* is adapted to the end of the gun barrel, and the joint made tight by a little lute, if necessary. The gas generated in the retort enters the receiver by the tubulure *e*, and, as it is obliged to pass by the very small aperture at *b*, it deposits the greater part of its potassium before it passes out by the tube *f*. It also deposits a certain portion on the other side of the diaphragm; and, finally, to collect the last portion which it may contain, a large glass tube is connected with the aperture at *f*, and its extremity generally is plunged into naphtha. The gas frequently takes fire, and must be extinguished, as well as the naphtha, if the flame should extend to it.

"The operation is known to be going on well by the regularity of the current of gas flowing through the tube *f*, the cessation of which indicates an obstruction of the gun barrel by a black substance accumulating in it, probably a compound of potassium, carbon and potassa. The tubulure *c* is then to be opened, it being generally closed by a cork; and by passing a ramrod, flattened at one end, through the apertures *c*, *b* and *e*, the tube is to be well cleared out. This, though quite necessary, must yet be done carefully; for a sudden rush of gas through the openings *e*, *f*, might cause serious accidents. M. Gmelin places the diaphragm of his receiver in the direction of its length, and is thus enabled to introduce the blade of a sword, by which he can clear the tube better than with a rod.

"The tube may easily be cleared two or three times, but at length it becomes so clogged up, that the process must be suspended, by first withdrawing the bars of the grate, and letting the fuel fall. Remove the retort, unscrew the tube, fill it with naphtha, and detach the substance which it contains; reunite it, replace the retort in the fire, and proceed to distil the remainder of its contents. In this way the operation may be repeated three or four times, and, using from 4 to 6 pounds of crude tartar, about an ounce of potassium will be obtained each time. By distilling the black matter detached from the iron tube, the half of its weight of potassium may be obtained.

"The potassium, prepared with charcoal, always contains carbonaceous matter, and requires to be purified by distilling it in divided portions from a glass retort, heated to redness in a sand bath, the neck being very much inclined, and plunged into a vessel full of naphtha."

2. SODIUM.

M. Serullas* gives the following *points of discrimination between potassium and sodium*. Potassium, placed on a mercurial bath, is at first still, but a motion, soon commencing, rapidly increases, owing to the absorption of atmospheric moisture and the consequent evolution of hydrogen by its decomposition. In dry air, contained in a receiver, these motions do not happen.

Sodium, as first observed by Gay-Lussac and Thénard, *combines with mercury with heat, light, and even explosion*. Sodium wastes away in water without combustion,† while potassium produces vivid light, and even incandescence; but when sodium is thrown upon a moderately strong solution of gum arabic, being detained, by the viscous nature of the fluid, the heat accumulates and combustion ensues, with a yellow instead of a violet flame, and the pieces run over

* Phil. Mag. Vol. VI, p. 149.

† This is true only of cold water; it scintillates, and even burns vividly on hot water, as I have often observed, agreeably to Sir H. Davy's original observations.

the surface of the liquid in the manner of potassium. If a piece of sodium be fixed upon a piece of wood and moistened with a drop or two of water, it inflames and flies immediately.

7. MAGNESIUM.

In addition to the slight notice of this metal in Vol. I, p. 274, I have now to add that it has been distinctly obtained by M. Bussy.*

The decomposition of the chloride of magnesia was effected by potassium, heated with it to redness in a porcelain tube. The magnesium, separated by washing, had the appearance of small brown scales, which, pressed by a pestle in an agate mortar, left a metallic trace, in color like lead. Magnesium is soluble in potassa and in muriatic acid, but not in diluted nitric acid. At a high temperature it burns, although with difficulty, and produces magnesia.

9. GLUCINIUM.

This metal has been distinctly obtained by M. Wöhler. *The glucina employed had been dissolved in carbonate of ammonia; it was then intimately mixed with charcoal and heated to redness in a current of dry chlorine gas; the resulting chloride was procured by sublimation, in the state of shining colorless needles, and also in a fused mass; it is very deliquescent, and dissolves in water with the disengagement of violent heat.*

Glucinium was obtained from the chloride by putting it into a platinum crucible with flattened pieces of potassium; the crucible was effectually covered, and heated with a spirit lamp; the reduction takes place instantaneously, and with so great an evolution of heat that the crucible becomes white-hot; the crucible when cold was opened, and inverted in a vessel of water; the fused mass of chloride of potassium and glucinium dissolved with a slight evolution of sulphuretted hydrogen, and the glucinium separated in the state of a gray-black powder, which was washed on a filter and dried; this substance has perfectly the appearance of a very finely precipitated and dried metal; by burnishing it acquires a dark metallic lustre. As it does not agglutinate at the violent heat at which it is reduced, it would seem to be very difficult of fusion; at common temperatures it oxidized neither in air nor water, not even when the water is boiling.

When heated on platinum foil, it inflames with great splendor, and becomes colorless glucina; but to produce this effect, it must be heated to redness: in oxygen gas, it burns with extraordinary splendor,

* Phil. Mag. Vol. V, p. 234, quoting Hensman's Repertoire de Chimie, for October, 1828.

and yet the resulting glucina shews no trace of fusion : if it is mixed with hydrate of glucina, (which happens when too much potassium is employed in the reduction,) a flame is perceived during its combustion in the oxygen gas, arising from the hydrogen which is disengaged during the action of the glucinium upon the water.

It readily dissolves in the sulphuric, muriatic, and nitric acids ; also in a solution of potassa and yields hydrogen. When heated in sulphuric acid, sulphurous acid gas is evolved. Unlike aluminium, it is not acted upon by ammonia : when *moderately heated in chlorine, it burns with great splendor, and sublimates as a crystallized chloride : when heated in the vapor of bromine, it burns with equal facility*, and the bromide of glucinium sublimates in long white needles : it is fusible, very volatile, and dissolves in water with great heat. *Heated in the vapor of iodine, it burns in the same manner*, and the iodide obtained sublimates in white needles ; in other respects it is similar to the preceding. It readily forms compounds also with sulphur, selenium, phosphorus, and arsenic.

11. YTTRIUM.

Yttrium was procured from yttria in the manner above described with respect to glucinium ; its texture is scaly, its color gray black, and lustre perfectly metallic ; the scaly texture distinguishes it from aluminium and glucinium. Its color and metallic appearance are inferior to those of aluminium ; one being to the other about as iron to tin. Aluminium appears to be a ductile metal, and yttrium on the contrary a brittle one : the latter at common temperatures is not oxidized either in the air or in water ; but when heated to redness, it burns with splendor, and becomes yttria. In oxygen gas, the combustion is of the most brilliant kind. The yttria obtained is white, and shows unequivocal marks of fusion. It dissolves in sulphuric acid, and less readily in a solution of potassa ; ammonia does not act upon it. It combines with sulphur, selenium, and phosphorus.

The bases of alumina, glucina and yttria are metals, which, at common temperatures, are not oxidized either in the air or water, but decompose water when acids are present ; and combine, and almost always with extraordinary heat, with oxygen, chlorine, bromine, iodine, sulphur, and selenium.*

12. THORIUM.† See p. 301, Vol. I.

* Ann. de Chim. et de Phys. XXXIX, 77.

† The mineral from which this metal is obtained is compact and brittle, semi-hard, has the vitreous fracture of Gadolinite ; powder dark brown ; sp. gr. 4.8 ; loses water under the blowpipe and becomes yellow. It consists of thorina 57.91, lime 2.58, oxide of iron 3.40, oxide of manganese 2.39, magnesia 0.36, oxide of uranium 2.58, oxide of lead 6.80, oxide of tin 0.01, silica 18.98, water 9.50, potash 0.14, soda 0.09, alumina 0.06, insoluble stony matter 1.40.—*Berzelius*.

Sec. XIII.—CERIUM.

1. **DISCOVERY.**—*In the Cerite,* by Hisinger and Berzelius, in 1804.*

2. **PROCESS.**—*Calcine, pulverize and dissolve cerite in nitro-muriatic acid; filter; neutralize with pure potassa and precipitate by tartrate of potassa, or by oxalic acid; this precipitate well washed, calcined and digested in vinegar, is oxide of cerium. Or, the nitro-muriatic solution is evaporated to dryness, the soluble part redissolved in water, and ammonia added in excess; the washed precipitate consists of oxide of iron and oxide of cerium; warm solution of oxalic acid forms an acid-oxalate of iron and an oxalate of cerium; the former being soluble in water, is removed by washing, and the latter which is insoluble, is heated in an open fire to decompose the oxalic acid, and pure oxide of cerium is obtained.*

3. **REDUCTION.**—*Vauquelin mixed tartrate of cerium with a very small quantity of oil and lampblack; he put it into a charcoal crucible, bedded this in sand contained in another crucible, and heated it in a forge for 1½ hour, when there was a partial reduction.*

4. **PROPERTIES.**

(a.) *A metallic globule was obtained hardly as large as a pin's head; this was among the coal, and none was discovered in the sand, although examined with the greatest care.*

(b.) *Vauquelin, supposing that the metal might be volatile, heated a similar mixture with the addition of borax, in a porcelain retort connected with a porcelain tube; there was no sublimate, but several small metallic globules remained in the retort, above and below, but all did not amount to $\frac{1}{8}$ of the cerium employed.*

(c.) *The metal was harder, whiter, more fragile, and more scaly in its fracture than pure cast iron.*

(d.) *Not acted on by any simple acid; dissolved with extreme difficulty in nitro-muriatic acid, even after trituration.*

(e.) *Solution reddish, and gave unequivocal traces of iron, but tartrate of potassa and oxalate of ammonia threw down a white precipitate, which, with the sweetish taste of the solution, indicated cerium.*

(f.) *It would appear probable that this metal is fixed, and that its oxide is volatile.†*

* Combined with silica and oxide of iron. For a description of the mineral, see Murray, 2d Ed. Vol. III, p. 623, and Nich. Dictionary, Art. Cerite. Found also in the ytthro-cerite and in the allanite, Nich. Jour. XII, 105.

† For more details, see Thénard, Vol. III, p. 489, 5th Ed.

Ann. of Philos. Vol. II. In an experiment made by Mr. Children, with his great galvanic battery, there was vivid combustion with a white flame, and a portion was volatilized, but whether of the metal or the oxide was not exactly determined.

(g.) **OXIDES.**—*There are two oxides of cerium.*—*The protoxide, when recently thrown down by a fixed alkali from its solution in acids, is white*; it becomes yellowish when dried in the air, and *when calcined, of a brick red*, in consequence of absorbing oxygen; *this is the peroxide*; it is soluble in several of the acids. *The white oxide is insoluble in water*; becomes red by the blowpipe, and with a large proportion of borax fuses into a globule, at first blood red, then yellowish green, and lastly colorless, unless the proportion of oxide is large when it is opaque and pearly.

(h.) **EQUIVALENT NUMBER.**—So little is known of this metal, that it is possible its equivalent may not have been exactly ascertained; it is supposed that the oxygen in the protoxide is to that in the peroxide as 2 to 3, and if cerium be represented by 46, the number of the protoxide will be 54, and that of the deutoxide 62.*

(i.) *The alkalis have no action upon cerium even by fusion*; potassa, in this way, reduces the red oxide to the white; ammonia renders the oxide yellowish without dissolving it; carbonated alkalis, both in the humid and dry way, dissolve a little and form triple salts.

(j.) *Sulphuric acid easily dissolves the white oxide, especially in the state of carbonate*; the solution is sweetish and not acid; it is colorless or slightly reddish, and by evaporation, gives white crystals; the acid diluted with from 4 to 7 parts of water, with heat, dissolves the red oxide; the solution is of an orange color, and, by evaporation, yields small prismatic crystals of the same hue; they are soluble in water with excess of acid; taste a mixed one, both acid and sweet. The crystals, by re-solution in water, are partly decomposed; a sub-sulphate is precipitated, and a super- or bi-sulphate remains in solution; obtained in small prisms by evaporation.

(k.) *Nitric acid easily dissolves the white oxide*—solution sweet with a degree of sharpness; does not crystallize, or only with difficulty; decomposed by heat and leaves a brick colored oxide.

In the cold, the red oxide is acted on feebly by the same acid, but is dissolved with the aid of heat; solution yellowish green; with an excess of acid, white crystals are formed; taste, at first pungent, then sweet; decomposed by heat; the neutral solution becomes only thick by evaporation—alcohol dissolves this matter, forming a red colored solution.

(l.) *Muriatic acid dissolves the red oxide—slowly in the cold, more rapidly with heat*; chlorine is disengaged with effervescence; the color of the solution is a faint greenish yellow; evaporated to a mel-

* Henry, 11th Ed. Vol. II, p. 98, and Thom. First Prin. Vol. I, p. 879. The equivalent of cerium has been stated at 50.—Hisinger. Ann. of Phil. Vol. IV.

litic consistence, it crystallizes confusedly, in a deliquescent mass; soluble in 1 part of cold water, and in 3 or 4 of alcohol; the concentrated alcoholic solution burns yellow and sparkling; if not concentrated, it burns without any peculiar color, but on agitation, emits white, red and purple sparks. Heat expels chlorine gas, and iron, if present, is sublimed as a muriate. Infusion of galls gives from the muriate a sparing yellowish precipitate; ammonia, a voluminous one becoming black and brilliant by desiccation, and by heat it becomes of a brick red.

(m.) *Chlorine does not dissolve the red oxide, but dissolves the white, which does not part with its oxygen.*

(n.) *Carbonated alkalies throw down carbonate of cerium from its acid solutions; it is a white light precipitate, which by drying, becomes of a shining and silvery appearance. Liquid carbonic acid combines with cerium, and if humid it attracts carbonic acid from the air; the compound is insoluble.*

(o.) *Phosphoric acid digested on it, forms an insoluble compound, and it may be produced by complex affinity; e. g. by phosphate of soda and muriate of cerium.*

(p.) *The white oxide unites with tartaric acid, but an excess of acid is required to render it soluble.*

(q.) *Ceric salts are decomposed by alkalies, and what appears to be a sub-salt is thrown down; if an excess of acid be present, triple salts are formed.*

(r.) *Prussiate of potassa precipitates the ceric solutions, white.*

(s.) *Hydro-sulphuret of ammonia produces a brown precipitate—but if an excess of the hydro-sulphuret be used, it is deep green.*

(t.) *Hydro-sulphuret of potassa gives a green precipitate, owing to iron; after subsidence, a fresh portion gives a white precipitate, similar to that by alkalies; it produces no effervescence with acids, and therefore does not appear to combine with sulphuretted hydrogen, nor to be reduced by it.*

(u.) *Phosphorus affords a white precipitate with muriate of cerium.*

(v.) *Iron and zinc do not precipitate its solutions.*

Sec. XIV.—COLUMBIUM, FORMERLY TANTALIUM.

I. HISTORY.—Discovered by Mr. Hatchett in 1801. *Found in 1809, by Dr. Wollaston, to be identical with tantalum.* Obtained from the columbite, tantalite, and ytthro-tantalite.†*

* See the chemical books for what was formerly said of the latter.

† See Murray, 2d Ed. Vol. III. p. 622.—Aikin's Dict. Vol. II, p. 401, and Vol. I, p. 314. The columbite is said, by Berzelius, to contain some oxide of tin, in mixture.

II. PROCESS.

(a.) *Either of these minerals is fused with potassa, or its carbonate, 3 or 4 parts, and then digested with muriatic or nitro-muriatic acid, and so on alternately.**

(b.) *The alkali unites with the new metallic oxide, (or acid, as it is often called,) and the acid with the iron, &c.*

(c.) *The alkaline solution is super saturated with an acid, and lets fall a white powder, which is oxide of columbium.*

III. REDUCTION AND PROPERTIES.

(a.) *This oxide, ignited with charcoal, affords a grayish black globule, having a metallic lustre, and the mineral acids change it again into a white oxide.†*

(b.) *But they do not dissolve the metal, even if boiled on it in any quantity.*

(c.) *Still, when fresh precipitated, its hydrated oxide is soluble in oxalic, tartaric, and citric acids.*

(d.) *Fixed alkalies in excess, (especially potassa by fusion,) dissolve the metal; carbonated alkalies dissolve the oxide, and it is precipitated again by acids, even by the carbonic.*

(e.) *If the excess of alkali is merely neutralized by the acid, infusion of galls causes an orange precipitate, but there is no precipitation with prussiate of potassa or its hydro-sulphuret; infusion of galls poured on the white oxide recently prepared and still moist, likewise forms the orange colored compound.*

(f.) *The oxide of the metal is white, and acquires no color by exposure to a high temperature with access of air. Sp. gr. of the oxide after ignition, is 6.500.‡*

* In his examination of the columbite of Chesterfield, (Mass.) Mr. Shepard (Am. Jour. Vol. 16,) tried to effect its decomposition, by igniting it alone, first with potassa and then with carbonate of soda, neither of which succeeded perfectly; he then employed a mixture of five parts of carbonate of soda, and two of calcined borax. This process proved nearly effectual; and in a succeeding trial, by the addition of two parts of nitrate of potassa to the same proportions of the other things, the whole of the mineral employed was decomposed.

† Mr. C. U. Shepard, in the Laboratory of Yale College, (Am. Jour. Vol. XVI, p. 224,) obtained the metal from the columbite of Chesterfield, (Mass.) He says—

I now introduced about 10 grains of the columbic acid into a small gimblet hole, made in a very compact piece of charcoal, stopping the orifice by means of a plug of the same substance. The charcoal was surrounded by sand in a covered Wedgewood crucible, and subjected to the heat of a powerful forge for one hour. On the cooling of the crucible, the columbic acid was found to be completely reduced into a porous, firmly cohering, metallic mass, of an iron grey color; and occupying nearly the same bulk as before its reduction. It was with difficulty impressible by the knife, and when recently scraped, showed a feeble metallic lustre. Specific gravity 5.671. It was brittle, and reducible to powder under the pestle. A portion of the powder was boiled for one hour in nitro-muriatic acid, without being made to undergo any change; but when fused along with potassa, it afforded a solution in water, from which the strong acids threw down the previously obtained white precipitate.

‡ This is considerably higher than that of the metal, but we have parallel examples in potassa and soda.

(g.) *Melts with phosphate of soda* and with borax, but without imparting to them any color.

(h.) *Oxide of tin and of tungsten are equally soluble with that of columbium in fixed alkalis*; but oxide of tin is easily reduced and furnishes a malleable metal; oxide of tungsten dissolves in ammonia, is precipitated and becomes yellow by acids, and colors soda and borax. Oxide of titanium is soluble in acids, and by fusion tinges borax and phosphoric salts.

(i.) *The great characteristics of columbium appear to be insolubility in acids, ready solubility in alkalis, and the peculiar yellow precipitate which its oxide gives with infusion of galls.*

(J.) **EQUIVALENT NUMBER.**—According to the analyses of Berzelius and Dr. Thomson, 144 is the equivalent number of Columbium, and the acid or oxide is composed of 1 proportion of metal 144, and 1 of oxygen 8=152.

IV. Miscellaneous.—Berzelius has discovered that metallic columbium may be obtained by heating in a tube a mixture of fluo-columbate of potassa with potassium. The mass becomes ignited, fluat of potassa is formed and columbium is liberated; water dissolves the alkaline fluat, and the metal appears in the form of a heavy black powder; when burnished it resembles iron.

Metallic columbium does not conduct electricity, but this may be owing to the want of unity in its parts. Ignited in an open vessel, it burns with a feeble flame, and with nitre it deflagrates. It burns vividly in chlorine gas; fluoric acid evolves from it hydrogen gas, and a mixture of fluoric and nitric acids acts on it with energy.* Reference may be had to the various papers contained in the Journals,† for the numerous details respecting the analysis and comparison of the columbic and tantalic minerals, as they are too extensive for a concise elementary work.

Remarks.—The mineral analyzed by Mr. Hatchett,‡ came from New London, in Connecticut, from the seat of Gov. Winthrop, by whom it was sent to Sir Hans Sloane, the founder of the British museum. It is now found at Chesterfield, Mass. as may be seen in Mr. Shepard's notice already quoted, and also in Haddam,§ Connecticut. In Sweden, the metal is called tantalum. It has been found also in the iron slag of Konigshutte, in Upper Silesia.||

* Ann. de Chim. et de Phys. Vol. XXIX, p. 303.

† Ann. de Chim. Vol. XLIII, p. 281; Thomson's Annals, Vol. IV, p. 467, and Vol. VIII, p. 233; Ann. de Chim. et de Phys. Vol. III, p. 140, and Vol. XXIX, p. 303; Phil. Trans. 1802 and 1809.

‡ Phil. Trans. 1802.

§ See Dr. Torrey's paper on the discovery of the Columbite. Ann. Lyc. of N. York, Vol. I.

|| Phil. Mag. Feb. 1828.

Sec. XV.—MOLYBDENUM.

I. HISTORY.—*Formerly, and for a long while confounded with black lead.**

II. PROCESS.—The only ores containing molybdenum are the bisulphuret of this metal, and the molybdate of lead,† and the former is preferred for the extraction.

(a.) *Distil sulphuret of molybdenum,† 1 part, with 4 or 5 or even 6 of diluted nitric acid or nitro-muriatic acid to dryness, or nearly so; return the contents of the receiver into the retort, add a little more acid and distil again and repeat this operation 3 or 4 times till the residuum in the retort is white as chalk; wash it well with warm water.‡ This is molybdic acid.*

(b.) It may be heated in a crucible to expel any remainder of sulphuric acid.

1. MOLYBDIC ACID.‖

III. PROPERTIES.—*It is a yellowish white heavy powder.*

(a.) *Taste acid and metallic—soluble in 960 parts of water at 212°; sp. gr. 3.4; solution pale yellow; little taste, but reddens litmus; fused by heat into a vitreous crystalline matter; when volatilized by a strong heat in an open crucible, the condensed vapor forms a scaly yellow powder.*

(b.) *Paper, by immersion in the solution of this acid and drying in the light, acquires a rich yellow color.*

(c.) *1 oz. of sulphuric acid, with heat, dissolves 10 grains of the molybdic acid, and becomes thick and blue.*

(d.) *Muriatic acid dissolves it by digestion—color pale yellowish green; saturated with potassa it becomes blue.*

(e.) *Fused with borax into a brownish yellow glass, and with microcosmic salt it forms a glass, varying from greenish to sky blue, according to the proportions.*

* The Greek word *μολυβδαίνα*, was applied by the ancients to denote several of the oxides of lead—the correspondent Latin word *plumbago*, (in French, *plombagine*; in English, *black lead*,) was formerly applied to all dark minerals, which are “light, friable, soft, of a greasy feel, and which stain the fingers and paper.” —*Thomson*. Scheele first distinguished between plumbago and molybdena, the latter being composed of sulphur, and a new metal, appearing on analysis, in the form of a pulverulent acid. In 1782, Hielm obtained a very small quantity of the metal, by exposing the acid to a violent heat mixed into a paste with linseed oil.

† See Aikin's Dict. Vol. II, p. 105, &c.

‡ By some it is regarded as a compound of sulphur and the oxide of molybdenum. Bucholz states the composition of the native sulphuret, as being 1 proportion of metal 48, + 2 of sulphur 32 = 80.

§ See Aikin, as above, for the steps of a full analysis.

‖ For a table of the effects of chemical reagents with molybdic acid, see Dr. Thomson's First Prin. Vol. II, p. 58.

(f.) *Nitrate of lead with a molybdic solution, gives a yellow insoluble molybdate of lead.*

(g.) *Prussiate of potassa, with a few drops of any mineral acids, throws down a copious brown precipitate.*

(h.) *Muriate of tin produces a deep blue tinge.*—Recent muriate of tin with the molybdate of potassa, forms a beautiful blue pigment.

The acid solution becomes blue by the immersion of a rod of tin or zinc.

(i.) *A similar but fainter tinge appears when it is boiled with filings of the easily oxidable metals.*

(j.) *It combines with alkalis; suffers a partial decomposition, and returns in part to the state of oxide.*

(k.) *Combinations with the alkalis are formed, by boiling them on the solid molybdic acid.*

(l.) *That with potassa does not crystallize.*

(m.) *That with soda gives four sided tables.*

(n.) *That with ammonia, a striated yellow mass.*

(o.) *Rich colored precipitates are formed by mixing different metallic solutions with alkaline molybdates.*

(p.) *Alkaline carbonates effervesce, if boiled on molybdic acid.*

(q.) *Solution of molybdic acid with sulphuretted hydrogen, being corked in a vial and shaken, the yellow color becomes blue.*

(r.) *Decomposed by sulphur, charcoal, &c.*

IV. METALLIC MOLYBDENUM.

(a.) *The powder of molybdic acid kneaded with oil and placed in a crucible lined with charcoal, is heated violently.*

(b.) *Only a very imperfect reduction is accomplished in this manner; the black mass that is obtained should be again made into a paste with linseed oil and heated as before; this being done 2 or 3 times, gives a complete reduction.*

(c.) *Sulphuret of molybdenum is calcined, till the sulphur is expelled, and it is reduced to a powder without fusion; by repeated digestions with ammonia, the molybdic acid is taken up and then reduced by ignition with charcoal.*

(d.) *Berzelius obtained metallic molybdenum, by passing a current of hydrogen gas over molybdic acid, ignited in a porcelain tube.*

(e.) *I find that a globule of metallic molybdenum can be easily obtained by heating the sulphuret upon charcoal, by the compound blowpipe; but as it burns away rapidly, it is somewhat difficult to hit the exact point, so as to stop when the sulphur is expelled or consumed; nor is it certain that none of it remains in the metallic globule, which is of grayish bronze color.*

(f.) *The metal has a yellowish gray color with metallic lustre*—according to Bucholz, it is silvery white, *fracture granular*, color of the fracture whitish gray, difficult to break, without ductility or malleability; *sp. gr.* 7., 7.4 and even 8.6.

(g.) *Generally in small brittle grains*; although Bucholz obtained it in pieces of 1 or 2 drachms.*

(h.) *From the united action of heat and air, a white oxide, or rather acid results*, which, by a high heat, is volatilized in small brilliant needles, like argentine flowers of antimony.

(i.) It was formerly thought that there were four degrees of oxidation; 1st. yellow or white, forming pure molybdic acid; 2d green or molybdenous† acid, obtained by dissolving the first in muriatic acid; 3d blue—muriate of tin gives it from either of the two former; 4th black, from heating molybdic acid with charcoal, but not to complete reduction: now, the four compounds are viewed as forming but three, two oxides and one acid;

1st, the protoxide, composed of metal 1 prop. 48+1 oxygen 8=56

2d, deutoxide—olim, molybdous acid 1 “ 48+2 “ 16=64

3d, molybdic acid 1 “ 48+3 “ 24=72

The protoxide is black or brown, and is obtained by heating to whiteness in a crucible with charcoal powder, the dried compound of molybdic acid and ammonia.

The deutoxide is brown, and is obtained by triturating 2 parts of molybdic acid in boiling hot water, with 1 of molybdenum, and then evaporating at a heat not over 120°, till the mixture becomes blue; or by heating a mixture of muriatic and molybdic acids, and expelling the former by heat, when, on adding water, it becomes of a fine indigo blue.‡

(j.) *Molybdenum is one of the most infusible metals*; the blow-pipe scorifies it by the external flame; ignition gives it a brownish yellow color, inclining to violet and indigo; when fully oxidized, it becomes the molybdic acid, and is white and soluble; it is formed also by deflagration with nitre, and remains combined with the alkali of the salt.

(k.) *Nitric acid oxidizes the metal with effervescence*, and converts it into blue oxide, and molybdic acid.

(l.) *Concentrated sulphuric acid, dissolves it at ebullition*, and becomes green; but this color, by long boiling, disappears almost entirely:

* Nich. Jour. Vol. IX, p. 132.

† Berzelius states that the blue molybdous acid of Bucholz “is a bimolybdate of the deutoxide of molybdenum;” that is a compound of two proportions of molybdic acid, with the peroxide of molybdenum.

‡ Thom. First Prin. Vol. II, p. 60.

(m.) *Chlorine*, as proved by Berzelius, *produces three chlorides of this metal*; the first is red and slightly volatile—the second, black, very fusible and volatile, and, both in the solid and vaporous form, resembles iodine; the third crystallizes in colorless scales.—H.

(n.) *Muriatic acid* has no action on the metal; but it is dissolved by the nitro-muriatic.

(o.) *Its salts are little known.*

(p.) The oxides easily pass to the acid state, and the acid to the state of oxide, so that it is not easy to ascertain the changes; solutions of the salts are generally, however, of a blue color, but can hardly be crystallized, without decomposition.

(q.) *The blue oxide forms with water, a solution of the same color*; by evaporation, it becomes deep grey, and when cold, bluish gray; it reddens blue paper more than molybdic acid; and with alkaline carbonates, produces a brisk effervescence, and a blue solution.

(r.) By heat, molybdenum 100 parts, combines with sulphur 67, and produces an artificial bi-sulphuret, like the natural, and molybdic acid 1 part + 5 of sulphur, produces a similar compound. Berzelius has discovered another compound, of sulphur 3 equivalents, and molybdenum 1, which is of a ruby red color, transparent and crystallized.*

(s.) *The sulphuret fuses with caustic fixed alkalis into a soluble deliquescent mass, of an uniform greenish color*; it exhales an hepatic odor, and muriatic acid throws down a copious black precipitate, probably hydroguretted sulphuret.

(t.) *Nitre*, 2 parts, with 1 of sulphuret of molybdenum, produces, *by detonation*, sulphate and molybdate of potassa.

(u.) The metal unites with phosphorus.

(v.) For its alloys with gold, silver, platinum, copper, iron, lead, tin, zinc, nickel, cobalt, manganese, bismuth, and arsenic, see Murray, 2d Ed. Vol. III, p. 400.

It is curious that it forms a fusible alloy with platinum. Molybdic acid precipitates nitrates of silver, lead, mercury, and baryta, and muriates of lead and baryta.

Remark.—Molybdenum, in small quantities, is of not unfrequent occurrence, in primitive rocks, and especially in those of the United States. It has hitherto been applied to little or no use, but its properties are so well marked, and some of them are so interesting, that should it be hereafter found in abundance, it may perhaps be applied to the purposes of the arts, especially for producing fine colors.

* Ann. de Chim. et de Phys. Vol. XXXII, p. 393.

Sec. XVI.—CHROMIUM.*

1. HISTORY AND NAME.—From *Χρῶμα*, Greek, color.

(a.) *Found by Vauquelin, (1797,) in chromate† of lead; and afterwards discovered in chromate of iron.‡*

(b.) *Our first object is to obtain chromic acid, from either of these minerals, and from the acid we can obtain the metal.*

CHROMIC ACID, AND ITS COMBINATIONS.

1st PROCESS.

(a.) *Pulverized chromate of lead 1 part, bi-carbonate of potassa 3, water 40—boil for 1 hour; there is an effervescence; the orange color of the chromate of lead becomes brick red; a golden colored solution of chromate of potassa is obtained, and a dirty yellow powder remains at bottom, consisting of chromate of lead, (undecomposed) and carbonate of lead.*

(b.) *Decant and preserve the solution; add dilute nitric acid to the residuum till effervescence ceases; to this residuum add 3 parts carbonate of potassa, and proceed as before, till the chromate of lead is all decomposed.§*

(c.) *A little weak nitric acid must be added to the chromate of potassa to decompose any unsaturated carbonate of potassa, viz. till effervescence ceases, and on evaporation, mixed crystals of nitre and chromate of potassa are obtained.*

2d PROCESS.

(a.) *Digest together, by a moderate heat, equal weights of pure strong muriatic acid, finely powdered chromate of lead, and distilled water, with constant stirring.*

(b.) *Muriate of lead precipitates, and chromic acid remains in solution; about one fourth as much more diluted muriatic acid is to be added and digested, till no more orange colored grains appear among the precipitate.*

(c.) *Mix the various liquors—heat them—let them stand for a few days in a cold place, that muriate of lead may be wholly precipitated, and finally, drop into the decanted fluid, very cautiously,*

* The importance which the combinations of this metal have assumed in the arts, has induced me to give a fuller account of it than of any of the metals, which have been usually regarded as possessing but a small degree of interest.

† It is the coloring matter of various minerals—its oxide colors the emerald, green; its acid the ruby, red. Chrome has been found in the state of an oxide, in the green ore which occurs with the red chromate of lead of Siberia, and it is a frequent element in meteoric stones.

‡ See the mineralogical books.

§ The nitrates of lead must be mixed and preserved, if we would ascertain how much lead is present.

oxide of silver, (precipitated from its nitric solution by potassa,) till the last portions added acquire a red purplish color.

(d.) *The liquors now contain nothing but chromic acid*, and bichromate of silver; after adding, cautiously, muriatic acid so long as it causes a precipitate, decanting the clear solution, and evaporating it, chromic acid remains.

3d PROCESS.

(a.) *In a silver or platinum crucible, heat to ignition, equal weights of finely pulverized chromate of iron,* and caustic potassa or nitre*; separate every thing which is soluble in boiling distilled water, and then digest with pure muriatic acid.

(b.) Repeat these alternate operations till all the solid matter is taken up.

(c.) *The evaporated muriatic solution*, when cold, *deposits gelatinous silica*, and another solution in water separates the earth; ammonia precipitates the iron from the clear solution.

(d.) *The alkaline solution is carefully neutralized by nitric acid*; the alumina is precipitated, and the solution now contains only chromate of potassa and nitre; by evaporation, the mixed crystals are obtained, as in (c.) process 1.

(e.) *To obtain the chromic acid*, from either of these solutions, we may add an equivalent quantity of a mineral acid, and on evaporation, we obtain, first, the salt formed by the acid and alkali, and then a mixture of the salt and *chromic acid*, in long ruby colored prisms.

(f.) Or, by adding nitrate of lead to the chromic alkaline solution, a yellow chromate of lead may be obtained, and afterwards decomposed.†

Solutions of nitrate of baryta, and chromate of potassa being mixed, suffer mutual decomposition, and the resulting chromate of baryta being digested in dilute sulphuric acid, forms sulphate of baryta, and liberates the chromic acid, which, by evaporation, is obtained in fine ruby red crystals. This is the usual mode of obtaining chromic acid.—*Murray*.

4th PROCESS.—*Digest chromate of baryta in dilute sulphuric acid*, equivalent to saturate the earth; the sulphate subsides, and the free acid remains in solution.

* This ore does not contain chromic acid, but peroxide of iron, 24 to 35 parts, and protoxide of chromium, 36 to 52, with the accidental bodies, silica, alumina, &c.: a fact which is said to have been first ascertained by M. Godon, in France.—Hy. and Th. Phil. Trans. 1827.

At Col. Gibbs' request, I analysed the Baltimore chromate of iron, in 1811, with a similar result, and communicated it to Dr. Bruce's Journal, but the number for which it was destined was never published, I had no copy, and the paper was lost.

† Vide Vauquelin's Memoir, Nich. 4to, Vol. II, p. 387, and Jour. de Mines, No. 34, p. 744, and No. 55, p. 522.

5th PROCESS.—*A hot concentrated solution of bi-chromate of potassa is decomposed by aqueous silicated fluoric acid; the double fluato of silica and potassa being nearly insoluble is chiefly separated, and the fluid chromic acid, after desiccation in a platinum capsule, is redissolved in the smallest portion of water, and thus the remainder of the double fluato, now insoluble, is separated by decantation, and the pure acid is obtained in solution.**

PROPERTIES OF CHROMIC ACID.

(a.) *Color, orange, or ruby red—taste, sharp and metallic, very soluble in water, and the solution, evaporated gently, either in the air or by heat, gives little long red prisms.*

(b.) *A paper wet with this acid, and exposed, during some hours, to the sun's light, assumes a green color, which is permanent in the dark.*

(c.) *Metals which easily absorb oxygen, such as iron, tin, &c. placed in this acid, give it the same color.*

(d.) *Ether and alcohol, boiled with it a few moments, produce a similar effect.*

(e.) *Heated, (whether solid or fluid,) with muriatic acid, it liberates chlorine, becomes deep green, and the solution is then capable of dissolving gold.*

(f.) *Hydro-sulphuret of potassa precipitates greenish brown flakes.*

(g.) *It boils under the blow-pipe on charcoal, and leaves an infusible green matter.†*

(h.) *It gives to phosphoric glass, and to borax, a beautiful emerald green color.*

(i.) *It imparts a red or yellow color, more or less deep, to its compounds.*

(j.) *It gives with mercury, (viz. by dropping an alkaline chromate into a mercurial solution,) a cinnabar red‡—with silver, a car-*

* Turner, 2d Ed. and Edinb. Jour. No. XVI, p. 175.

† Mr. A. A. Hayes, Am. Jour. Vol. XIV, p. 136, remarks that "chromic acid, when dry, is yellowish brown; its solution, when somewhat diluted, is yellow with a shade of brown; the solution has an acid and astringent taste; it bleaches litmus and blue paper; it does not afford crystals by evaporation, but is reduced to a yellowish brown slightly deliquescent crust. At a temperature below the boiling point of mercury, it fuses with bubbling, and is partially decomposed; at a red heat, it becomes the protoxide. It may be obtained by dropping muriatic acid into a mixture of chromate of silver and distilled water, until the red brown color of the chromate is reduced to white, with a tinge of red; at the same time filtering, and cautiously adding a few drops of muriatic acid, till a white precipitate ceases to be formed. When large quantities are required, the bi-chromate of lead may be added to strong muriatic acid, and the mixture placed on a warm sand bath for a few hours, occasionally stirring the mass. Water may then be added, and filtered from the chloride of lead, and the filtered fluid used instead of the muriatic acid, in decomposing the chromate of silver; in either process, a solution of pure chromic acid is obtained. This acid possesses the property of coloring salts which crystallize in its solution.

‡ The precipitate is, according to circumstances, either a red di-chromate; a lemon yellow neutral chromate; or, an orange colored mixture of the two.—G. Chilton.

mine red—lead, orange yellow—zinc and bismuth, yellow—copper, cobalt and antimony, give dull colors—tin, green.

COMBINATIONS WITH ALKALIES.

(a.) *Chromic acid combines with earths, alkalies, and metallic oxides, and produces chromates.*

(b.) *The salts are formed as already stated in the above articles; they are soluble and crystallizable—the color is generally orange yellow, and the crystals are of the same color, only a little deeper.**

(c.) *Chromate of Potassa.*—It is obtained by neutralizing a solution of the bi-chromate; by subsequent evaporation and rest, the crystals are deposited. They are minute prisms, of five and six sides; the color is lemon yellow; this salt is very soluble in water, and the solution is alkaline.

(d.) *Bi-chromate of Potassa.*—When crystallized without the presence of other salts, it presents rhombic tables, truncated on their obtuse lateral edges; its color is pure orange-red; crystallized in an acid solution, its color is red-brown. Sulphuretted hydrogen gas, decomposes this salt, and gives a precipitate of oxide of chromium, mixed with sulphur.†

* The most economical process, and the one generally adopted, both in chemistry and the arts, is by decomposing the chromate of iron, by nitre. The chromate being pulverized, is mixed with half its weight of nitre, and heated strongly in a crucible for an hour or two; the chromic oxide, acidified by the oxygen of the nitre, is thus transferred to the alkali, and becomes chromate of potassa, mixed with oxide of iron. By repeated digestion in hot water, the alkaline chromate is obtained, and the excess of alkali being saturated by a little nitric acid, the fluid will, by repose, give yellow crystals of chromate of potassa, in beautiful prisms. Red chromate of mercury is obtained from the solution of the chromate of potassa, by adding nitrate of mercury, and this mercurial chromate being decomposed by heat, allows its mercury to be volatilized, and the oxide of chromium remains. In the arts, skittle pot crucibles are about $\frac{3}{4}$ filled with the nitre, and chromate of iron, the nitre being from $\frac{1}{2}$ to equal weight: the crucibles are gradually heated, and at last kept ignited for half an hour, when they are broken, the contents ground, and with the fragments of the crucibles, boiled for half an hour, with ten times their weight of water, and the boiling repeated with more water, till it is no longer colored; the mixed fluids, considerably evaporated, are then saturated with nitric acid, to precipitate the silica and alumina, the liberated chromic acid, after filtration, is again saturated with potassa till it is again yellow; a first evaporation separates the nitrate of potassa, and a second, after cooling, precipitates the yellow crystals of chromate of potassa; the mother water, by new evaporation, deposits orange red crystals of bi-chromate of potassa, and by another evaporation, more of these crystals, and lastly, being still further evaporated, yellow crystals of chromate of potassa are obtained.—Gray's Op. Chem. 750. The bi-chromate of potassa is usually made by acidulating the chromate of potassa with nitric or sulphuric acid; after a day or two, the red bi-chromate, the most splendid of all the salts, will crystallize in square tables.

† Bi-chromate of potassa is anhydrous, and is not changed by a red heat; its composition is potassa 1 propor. 48+chromic acid 2 prop. 104=152 its equivalent. This salt is manufactured in large quantities at Glasgow, for dyeing and printing calico, and as a pigment; likewise at McKims' chemical works, Baltimore, where the salt is produced in splendid and well formed crystals.—J. Griscom.

(e.) *Chromate of Soda, of a fine transparent yellow, contains 12 proportions of water.*

(f.) *Chromate of Ammonia.*—The crystals are minute prisms, which are aggregated so as to present brilliant thin plates, like flakes of gold, resembling the form of the index used in writing; its color is yellow, and its lustre is metallic. It is formed by neutralizing chromic acid by ammonia, or by decomposing bi-chromate of mercury by the same alkali. It is a beautiful salt. *Chromate of ammonia is decomposed by heat, leaving green oxide of chromium.*

(g.) *Bi-chromate of Ammonia.*—The crystals are rhombic prisms; color, red-brown; less soluble than the chromate. When heated on platinum foil, at a temperature below redness they are decomposed, with the evolution of light, and a slight detonation; oxide of chromium remains.*

(h.) *The ammoniacal salts give oxygen gas by heat, and the residue is of a green color.*

(i.) *The earthy salts do the same;* the alkaline chromates are, by double affinity, decomposed by the soluble salts of baryta, lime, strontia, and magnesia.

(j.) *The earthy chromates, in general, are less soluble than the alkaline.* Godon says,† that chromate of lime is soluble and crystallizable.

(k.) *Chromate of baryta is yellow*—that of lime, orange yellow.

(l.) Much has been already done with chromic preparations, and much may be expected, in forming paints, enamels, for coloring porcelain, &c.

THE METAL CHROMIUM.

(a.) 72 parts of *chromic acid* were placed in a charcoal crucible, contained in one of hard porcelain filled with charcoal powder, and being heated powerfully for 1 hour, in a forge of 3 tuyers, it gave a *metallic mass*; white,‡ gray, brilliant, very brittle, and on the surface were many crystals in barbs or plumes, which were perfectly metallic in their appearance.

(b.) *Structure granular*, and in interlaced needles, leaving spaces between; sp. gr. 5.9.§

(c.) *Tarnishes superficially by the blowpipe*, and becomes externally green—no signs of fusion.

(d.) *Does not fuse with borax*, but imparts to it an emerald green color.

(e.) *Even when in powder, this metal is oxidized with difficulty by strong boiling nitric acid*, and gives the acid a green color verging to

* Hayes, in Am. Jour. Vol. XIV.

† Ann. de Chim. Vol. LIII, p. 224.

‡ White with a tinge of yellow; its powder has the metallic lustre: it is not magnetic.

§ Dr. Thomson found it a little above 5.

blue—repeated operations are necessary to convert it into chromic acid.

(f.) Heated in a crucible with *potassa or soda*, it *absorbs oxygen*, and gives a yellow chromate.

OXIDE AND ACID.

There appear to be one oxide and one acid of chrome.

1. The green* oxide, according to Dr. Thomson, is composed of chromium 1 proportion 32, + oxygen one, 8=40.

2. The acid, “ 32, + “ $2\frac{1}{2}$, 20=52.

The anomaly of a half equivalent may be avoided by supposing the chromic acid to be composed of 2 equivalents of chromium and 5 of oxygen; it has long been agreed that the equivalent of chromic acid is 52.

It has been already stated, that the protoxide may be obtained by decomposing the chromate of mercury by heat. Or, if to the boiling aqueous solution of the chromate of potassa, equal measures of alcohol and strong muriatic acid be added, till the liquid is green, ammonia, added in excess, throws down the hydrated oxide, and a pale greenish powder is obtained, containing 29.25 grs. of water to $4\frac{1}{2}$ of the dry oxide; a greater proportion of water by far than is known in any similar case. This hydrate is very easily soluble, while the dry oxide is scarcely soluble at all in acids. By dissolving it in muriatic acid, adding a slight excess of ammonia, and washing the precipitate, the hydrated oxide is obtained perfectly pure.

The dry protoxide is tasteless, unaltered by heat, becomes chromic acid by deflagration with nitre, and by fusion imparts a fine emerald green color to borax or other saline flux, a property which is highly characteristic.

When heated nearly to redness, it becomes suddenly ignited, and presents the appearance of combustion; an effect first observed by Berzelius, and by him referred to internal change of form, consequent to rapid contraction. This interesting character is exhibited, when we place a few grains of the dry oxide in a platinum spoon, gently press it, so as to distribute it equally over the surface and cause it to slightly cohere, and subsequently heat it by the blowpipe flame; the oxide is partly dispersed by the sudden action. If considerable quantities of the oxide be heated in a capsule, the ignition commences at the surface in contact with the dish, and sufficient heat is developed, to continue the action throughout the mass.†

* A brown oxide was formerly admitted, and by some it was called chromous acid; it is obtained by passing sulphurous acid gas through the solution of chromate or bichromate of potassa, and washing the brown precipitate with water which removes most of the acid and leaves the remainder, 1 equivalent, combined with 6 of green oxide; but it appears that these proportions vary with the mode of preparation.

† A. A. Hayes, Am. Jour. Vol. XIV.

SALTS OF CHROMIUM.

They must not be confounded with the salts formed by chromic acid ; in the latter, the oxidized chromium performs the functions of an acid ; in the former, of a base.

The hydrated oxide is the only form in which chromium can be easily dissolved, to produce salts ; or what amounts to the same thing, by boiling the chromic acid with other acids and alcohol, it is converted into the oxide and then dissolved.

According to Dr. Thomson, most of the salts which have protoxide of chromium for a base, have a deep green color, but some are blue and a few purple, and even very dilute solutions are still opaque ; their taste is strong but rather agreeable.

For a fuller account of the oxides and salts of chromium, I must refer the reader to Dr. Thomson's First Principles, to his paper in the Philosophical Transactions, 1827, p. 159, and to the paper of Mr. Hayes.* The following particulars are all that can be admitted consistently with our limits.

Nitric acid forms with the protoxide of chromium a solution, which, if seen by reflected light, is green, but by transmitted light, especially of a lamp, it is red.

Muriate of chromium is, when dry, a transparent green powder, and is ultimately decomposed by heat.

Sulphate of chromium forms a neutral green solution of an astringent taste ; when dry, it is blue green and transparent ; but neither of the above salts is crystallizable.

Chromic acid dissolves moist oxide of chromium,† and forms a neutral yellowish solution ; it does not crystallize. Many of the chromic salts are formed by double exchange.

FLUO-CHROMIC ACID.

(a.) *Discovered in 1825, by M. Unverdorben.‡ It is obtained by distilling in a leaden retort a mixture of fluor-spar, chromate of lead, and fuming or even common sulphuric acid, and the fluoric acid in the form of a thick yellow or red vapor, rises combined or mixed with chromic acid.*

(b.) *It appears red in the air, because the atmospherical water decomposes it and precipitates chromic acid in small red crystals. It readily attacks glass, and is rapidly absorbed by water, which acquires an orange tint, and then contains the two acids dissolved.*

* Am. Jour. Vol. XIV.

† This compound is called chromate of chromium.

‡ Edinburgh Jour. of Science, No. 7.

(c.) *By evaporation, pure chromic acid is obtained, the fluoric acid being volatilized.*

(d.) *When the gas is received into a deep and moistened platinum vessel, the water is soon saturated, the fluoric acid is dissipated, and the chromic acid is precipitated like a red snow; when ignited in a platinum vessel, it melts, and explodes with a flash, being decomposed into oxygen and protoxide; but the crystals obtained from water do not give a similar result.*

(e.) *Crystals of chromic acid are decomposed, in ammoniacal gas, with explosion and light, and a protoxide of the metal results; a similar effect happens when ammoniacal gas is mixed with fluo-chromic gas or vapor.*

CHLORO-CHROMIC ACID.

1. PROCESS.

(a.) *Triturate and intimately mix 190 grs. of bi-chromate of potassa with 225 of common salt. In a tubulated glass retort, adapted by a cork to a dry glass receiver, mix this powder with 500 grs. of common sulphuric acid,* and apply a lamp heat.*

(b.) *There is an effervescence, and beautiful red fumes soon appear, which condense and drop into the receiver in the form of a red liquid; 10 or 15 minutes finish the process, and the liquid in the retort is now green. About 200 grs. of the red liquid are obtained from the above quantity of materials.*

(c.) *Chromate of lead, or chromate of potassa may be substituted for bi-chromate of the latter.*

2. PROPERTIES.

(a.) *Color, deep crimson; opaque, except in thin films; odor, like that of chlorine; taste, sweetish, astringent, and acid.*

(b.) *Reddens vegetable blues.*

(c.) *Sp. gr. 1.9134, but its extreme volatility renders it difficult to obtain its exact gravity.*

(d.) *Sinks in water, and the drops resemble oil; chlorine gas is emitted rather copiously, and a greenish yellow fluid results, containing muriatic and chromic acids, and a little green oxide of chromium.*

(e.) *Dropped into alcohol, of sp. gr. .840, it produces heat and combustion; and the same effect happens with oil of turpentine; by this action, the fluid is reduced to the state of green oxide of chromium.*

(f.) *It heats and inflames sulphur and phosphorus,† and the vapor detonates with ammoniacal gas.*

* The process is easiest when the quantity of acid is sufficient to produce a semi-fluid magma.

† The latter according to Dumas; phosphorus did not inflame in Dr. Thomson's experiments. The experiment requires caution, as the inflamed phosphorus is generally thrown about with great violence.—J. T.

(g.) No action on charcoal, oxygen, chlorine, iodine, nitric and muriatic acids, and indigo.

(h.) It acts on olive oil with heat and effervescence, and sometimes the oil is inflamed.

3. COMPOSITION.—Chromic acid 1 equiv. 52

Chlorine “ 1 “ 36

—
88 its equivalent.*

Dr. Turner remarks, that it may be regarded either as a compound of muriatic and chromic acids, or of chlorine and chromium; but it is stated that M. Dumas has discovered that the pure chloride of chromium is a fluid, obtained by passing the gas of Unverdorben, through a cold tube, and that its taking the gaseous form is owing to the muriatic acid with which it is mixed.

MISCELLANEOUS.

It is now agreed, that the chromate of iron was improperly so named, and that it is not a compound of chromic acid and oxide of iron, but of the latter with oxide of chrome.†

The principal use of chromium is in forming pigments, particularly the chrome yellow and the bi-chromate of potassa. By boiling carbonate of lead 67 parts, with chromate of potassa 82 parts, in a sufficient quantity of water, Dulong obtained a red sub-chromate of lead, composed of 2 proportions of protoxide of lead and one of chromic acid; it is called a di-chromate, and is recommended as a pigment.‡

Chromic preparations are used in dyeing.—Silk, wool, cotton, or flax, being placed in a dilute solution of sub-acetate of lead, at 122° to 150° Fahr., then washed with much water, and next plunged into a solution of neutral chromate of potassa, they acquire, in about ten minutes, the full intensity of color, which, if the stuffs are plunged into acetic acid, becomes instantly of a very brilliant orange; or the same color is produced, if the neutral acetate, or crystallized nitrate of lead is used. Soap does not alter these colors in the cold; at 212° it weakens the shade, but vinegar restores it; it is however instantly destroyed by carbonate of soda, and by muriatic acid.§

* For the proofs, see Dr. Thomson's Memoir, Phil. Trans. 1827.

† That of Baltimore, according to Mr. Seybert, is composed of 39.5 protoxide of chromium, 36 protoxide of iron, 13 alumina, and 10.5 silic. Am. Jour. See also Ann. de Chim. Vol. XXV and LXX. Ann. de Chim. et de Phys. Vol. XIV, p. 299; XV, 67; XVI, 400; XVII, XXII, 51; LXXXII, 292. Ann. Philos. Vol. IV, XVI, and IX, p. 303. Dr. Thomson's First Prin.

‡ Ann. Philos. N. S. IX, 303. It is a good oil color, and mixes well with white lead; as a water color also, it stands well in exposed situations.

§ Thenard, 5th Ed. Vol. IV, p. 218.

The coloring power of the chromate of potassa is so great that 40,000 parts of water are sensibly tinged yellow by one of this salt.

The chrome yellow, (chromate of lead,) was first made in this country by Mr. Godon, who supplied cabinets with small portions, as specimens.

We owe the manufacture, on a scale sufficient for the demands of the arts, to Mr. George Chilton, who, by the beauty and permanency of the pigment which he made, overcame the doubts of the painters, and the hesitancy of the dealers, and the manufacture is now successfully prosecuted in the U. States, by other persons, and in various places. I have beautiful specimens of chromate and bi-chromate of lead, chromic acid, and green oxide of chrome, made several years ago by Mr. Chilton.

Chromate of iron is diffused through the New Haven and Milford marble and serpentine, and with oxide of iron, probably forms the fine green, and all the other colors. The most abundant American locality is near Baltimore, at the Bare Hills. It is found also in the Shetland islands, in France, and in other countries.

SEC. XVII.—TITANIUM.

I. HISTORY.—Discovered in 1781.*

II. PROCESSES.—*Obtained from its ores*†—1. Titanite or red shorl. 2. Anatase or octahedrite. 3. Menachanite. 4. Titan siliceo calcaire or sphene. 5. Iserin; for the description of all which see the mineralogical books.

1st PROCESS—*on the titanite.*

(a.) *Fixed alkali is the only reagent sufficiently active* for these researches, and carbonated alkali is, in many cases, preferable to the caustic.

* There is black sand, considerably resembling gun powder, found in the valley of Menachan in Cornwall, (England,) which was examined by Mr. Gregor, (A. D. 1781.) He concluded that it consisted of oxide of iron, and a new metal, although he was not able to obtain it in a separate state.

In 1795, Klaproth published an analysis of a crystallized mineral, found frequently in gneiss rocks, and before known to mineralogists by the name of red shorl. Although he was unable completely to reduce it, he found reason to conclude that it consisted wholly of the oxide of a new metal which he named *titanium*. He afterwards examined the black sand from Cornwall, and found it to contain the same substance.

Titanium has been found in the octahedral iron ore from Elba; in chrichtonite; in black mica; in some feldspars and serpentines, and in the specular iron ore of Elba. A pure oxide of titanium has been obtained also in the form of pale yellow crystals from the diamond mines of Brazil; they agree in form with the anatase. Henry, 11th Ed. Vol. II, p. 99, and Eng. Quar. Jour. XXII, 409.

† See Klaproth's Analytical Essays, Vol. I, p. 214. Journal des Mines, No. 19, p. 58, and No. 15, p. 21.

(b.) *The ore, very finely pulverized, is mixed with three times its weight of carbonate of potassa and fused in a platinum crucible; if iron and manganese are present, a green color results, otherwise, the color is pearl gray.*

(c.) *Every thing soluble in hot water being extracted from the pulverized mass, a gray powder, which is a compound of titanium and potassa, remains.*

(d.) *It is dissolved in strong muriatic acid, and on dilution with water and boiling, the greater part of the oxide of titanium falls.—It is then washed on a filter with acidulated muriatic acid; it is digested, while still moist, with hydro-sulphuret of ammonia which turns the oxides of iron and manganese into sulphurets, but does not act on the oxide of titanium. The sulphurets are removed by dilute muriatic acid, and the washed titanium is ignited.**

2d PROCESS.

(a.) *Titan siliceo-calcaire or sphene.*—Ignite 100 grs. with 400 of caustic potash, for one hour; soften the mass with water, and digest with excess of muriatic acid; a solution of the whole is obtained except 12 grs. of silica; decompose the muriatic solution by carbonate of potassa, wash and dry the precipitate, and again digest with muriatic acid; 23 grs. of silica are left; add caustic ammonia to the preceding solution; oxide of titanium, of a yellowish white, is thrown down, and after ignition, amounts to 33 grs.

(b.) *The residual fluid, being saturated at a boiling heat by carbonate of potassa, gives 33 grs. of carbonate of lime.*

3d PROCESS.

(a.) *Menachanite.*—100 grs. with 400 grs. caustic potash, are ignited for 1½ hour; the fused mass is green and gives a green solution with water, while a brick red powder of 124 grs. remains.

(b.) *These 124 grs. being boiled for 1 hour in caustic potash, and saturated with muriatic acid, 3 grs. of oxide of titanium fall, when carbonate of potassa is added.*

(c.) *The residue of the 124 grains being digested with dilute muriatic acid, it acquires a yellow color, and leaves 46 grs. of a reddish white powder, viz. oxide of titanium; the yellow muriatic liquor gave, by ammonia, 50 grs. of brown oxide of iron.*

(d.) *The green alkaline solution is super-saturated with muriatic acid, and becomes bright red, which color disappears by evaporation; the saline residuum is entirely soluble in water, which proves that silica is not present; add carbonate of potassa, and there is a precipitate of 2 grs. of carbonated manganese.*

* Turner, and Ann. de Chim. et de Phys. XXIII.

4th PROCESS.—The processes upon the titanic ores are numerous, and they require to be varied in different cases ; the following is by Prof. Rose, of Berlin.

(a.) *After obtaining, as in process 1, the mixed solution of iron and titanic oxide (or acid) in muriatic acid, ammonia is added in excess—and although it produces no precipitate, hydro-sulphuret of ammonia throws down the iron, without affecting the titanium. The fluid, on evaporation, affords the titanic acid or oxide which is calcined with free access of air.*

(b.) *Titanized iron is most frequently used, because it is more abundant than rutile ; in fine powder, it is exposed, in a porcelain tube, to the action of sulphuretted hydrogen gas ; the iron is converted into a sulphuret, which is removed by muriatic acid, and after ignition, to expel the sulphur, the titanic acid is obtained ; but to have it quite pure, it may be necessary to repeat the process.**

III. REDUCTION.

(a.) *The oxide is mixed with fish oil and placed in a crucible, lined with a mixture of clay and charcoal, and heated intensely for three hours ; a blackish spongy mass is obtained, which, in some places, has a reddish metallic appearance.*

(b.) *100 parts native titanite being mixed with 50 of calcined borax and 50 of charcoal powder, the mixture was heated for 1½ hour in a forge ; an agglutinated brittle mass was obtained, resembling copper in external lustre and color, and if broken while yet hot, it passes to purple and blue.*

(c.) *The gallate of titanium, decomposed by potassa, and heated strongly with charcoal powder, in a charcoal crucible, affords a metallic mass of a dark copper color, and somewhat brilliant.†*

IV. THE METAL.

The properties of metallic titanium were scarcely known until 1822, when Dr. Wollaston ascertained, that the metal had been accidentally produced at the bottom of a great iron smelting furnace, at Merthim Tydvil, in Wales ; at Low Moor, in Yorkshire ; at the Clyde Iron Works, in Scotland ; and other places, where the crystals of titanium had been mistaken for Iron pyrites.

1. PROPERTIES.

(a.) *In small cubes having the color and lustre of burnished copper, harder than steel, glass, or even rock crystals, or agate, on the polished surface of which, a sharp angle of the cubes will write.*

* Henry, 11th Ed. Vol. II, p. 100, and Ann. de Chim. et de Phys. Vol. XXXVIII, p. 181. In place of the ammonia, Laugier adds oxalic acid, which combines with the titanium, and the oxalate being calcined, the oxide of titanium remains pure.

† This is the process of Lampadius, and succeeded better than any other.

(b.) *Sp. gr.* 5.3; conducts even the feeblest electricity; slightly magnetic, from a little adherent iron; and after being acted on by muriatic acid, Dr. W. inferred that it still contains $\frac{1}{8}$ of iron.

(c.) *Very infusible*, not melted by the blow-pipe, but slowly oxidized by long continued heat, becoming covered with a purple, or even red film of oxide.

(d.) *Not affected by the strongest acids*; completely oxidized by being heated with nitre, and especially with nitre and borax, the latter, constantly dissolving the oxide produced by the former; the addition of soda facilitates the process. The result is the white, or peroxide of titanium.

(e.) The crystals, fused with equal weights of borax, and dry carbonate of soda, become soluble in muriatic acid; the metal is precipitated by continued boiling, and by alkalis, but is not soluble in them, even in excess. The muriate of the oxide, dried at 212° , loses any excess of acid, is again soluble in water, and is in a good state for experiments.*

V. OXIDES.

(a.) *Two*.—*Protoxide*, as in *anatase*, or *octahedrite*; color blue.†

(b.) *Peroxide*, as in the *rutilite*, in which its color is probably derived from iron, as the peroxide is white.

(c.) From its combining with a few bases, it has been called the *titanic acid*, but its affinities are very weak, and it appears scarcely worthy of having that rank.‡

(d.) *The peroxide is infusible*; becomes yellow by heat, white again when cold, and is then insoluble in acids. Constitution: titanium, 1 prop. 32 + oxygen 2 = 16 = 48. The oxide of titanium is not reduced by the galvanic battery.

VI. MISCELLANEOUS.

(a.) The native red oxide is insoluble in the strongest acids, even when aided by digestion; after being fused with carbonate of potassa, it becomes then in a degree soluble.

(b.) The nitric solution affords, by spontaneous evaporation, rhomboidal crystals.

(c.) Muriatic acid produces transparent crystals. It is supposed by Mr. Rose, that these are not true salts, but compounds of the peroxide with alkali.

(d.) Prussiate of potassa gives a green§ precipitate, mixed with brown; but a pure solution of titanium produces a red, inclining to orange.

* Phil. Trans. 1823.

† From the muriatic solution of titanic acid with potassa, a plate of zinc precipitates the blue oxide: if ammonia or potassa is then added, the water will be decomposed, and the blue oxide of titanium will become, white or peroxide.—Rose.

‡ Ann. Phil. N. S. Vol. VI, p. 361.

§ The green supposed to be owing to iron.

(e.) Tincture of galls, gives a brown red.*
 (f.) Hydro-sulphurets, a dirty dark green.
 (g.) A rod of tin, a fine red color; one of zinc, a deep blue.
 (h.) Forms with borax, a glass of hyacinthine red.
 (i.) *Does not combine with sulphur*, nor does sulphuretted hydrogen precipitate it; but vapor of sulphuret of carbon, passed over the ignited peroxide, generates a sulphuret. It is of a deep green color, and by friction obtains a strong metallic lustre.

(j.) *It forms no alloys*, unless with iron, as in the crystals examined by Dr. Wollaston;† and an alloy of that metal is obtained by heating the oxide of titanium with iron, oil, and charcoal powder.

(k.) Both the white oxide of titanium, and rutilite, give a straw yellow color to enamel flux, and oxide of titanium has been used as an ingredient in the rich brown, for porcelain painting, but it was difficult to obtain an uniform tint.‡

(l.) *Chloride of titanium is formed by passing dry chlorine over the pulverized crystals from the iron slag*, contained in an ignited tube; a fluid condenses in the cooler part of the tube; it is limpid, fuming, and boils a little above 212° : a drop of water rapidly expels chlorine, and when water was not in excess, a solid muriate was formed.§

CONCLUDING REMARKS.

Titanium is found in many places, and in no country more frequently than in the U. States, where, according to its well known geological relations, it frequents primitive rocks.

It is a much more generally diffused substance than was formerly imagined, and may, perhaps, become hereafter useful.

SEC. XVIII.—TELLURIUM.

I. DISCOVERY AND NAME.

In 1782, by *Muller*, while examining the gold ores of Transylvania: confirmed by *Bergmann*, and more fully by *Klaproth*,|| in 1798, who called the new metal *tellurium*, after *tellus*, the earth, in accordance with the ancient method of naming the metals after the planets.

* Looks like coagulated blood, if concentrated, and when dried, resembles kermes mineral.

† Berchier regards Dr. Wollaston's titanium as a titaniuret of iron.—J. T.

‡ The native oxide of titanium was formerly much used at Sevres, but for the reason stated in the text, was given up. It is employed to give a strong yellow color to the porcelain.

§ Ann. Phil. N. S. Vol. IX, p. 18.

|| Klaproth's Contributions, Vol. II.

II. NATURAL SOURCES.

Obtained from its ores, in all* of which it exists in the metallic state; but combined or mixed with different metals. The principal ores are—

1. *White native Tellurium*.—Sylvanite, aurum paradoxum or problematicum.

2. *Gray native Tellurium*.—Sylvane graphique, aurum graphicum.

3. *Yellow Native Tellurium*.—Sylvane blanche, (Broch.) tellure natif aurifère et plombifère of Haüy.

4. *Black native Tellurium*.—Sylvane lamelleux, (Broch.) tellure natif aurifère et plombifère, (Haüy.)

III. PROCESSES—ANALYSIS.

1. *Of the White Tellurium*.

(a.) Take of the ore 100 parts, with 600 muriatic, and 300 nitric acid, added slowly, at intervals; the action is violent, and all is taken up except the gangue.

(b.) The solution is diluted, as much as may be without decomposition; add caustic fixed alkali until the copious precipitate is all dissolved, as far as it is soluble in this menstruum; oxides of gold and iron remain, of a dark brown color, and slimy consistence.

(c.) This residuum is dissolved in nitro muriatic acid—add nitrate of mercury, (made in the cold) drop by drop, as long as the precipitate appears brown; it is gold and muriate of mercury; it must be ignited with borax in a crucible; mercury is expelled, and a button of pure gold remains.

(d.) To the nitro-muriatic solution, (c.) add caustic alkali, and the oxide of iron is thrown down.

(e.) The alkaline solution, (c.) of the oxide of tellurium, is saturated with muriatic acid, and heated; oxide of tellurium, a white heavy powder, is precipitated; it is washed in a mixture of equal parts of alcohol and water,† and gently dried, preparatory to its reduction.

(f.) This ore contains 92.55 tellurium, 7.20 iron, 0.25 gold.

2. *OF THE GRAY TELLURIUM*.

(a.) Digest in nitro-muriatic acid, till nothing more is taken up.

(b.) Quartz and muriate of silver remain; fuse with 5 parts of carbonate of soda and obtain pure silver.

(c.) The nitro-muriatic solution, being greatly concentrated by evaporation, is largely diluted with alcohol, when oxide of tellurium precipitates; redissolve it in muriatic acid, and precipitate it again by a bar of iron, when it will fall in black metallic flocculi.

* Selenium is found in one of its ores.

† Because water alone would dissolve it.

(d.) The last nitro-muriatic solution gives up its gold, (after the precipitation of the tellurium,) by adding green sulphate of iron.

(e.) This ore contains tellurium 60., gold 30., and silver 10.

3. OF YELLOW TELLURIUM.

(a.) 400 grains of the ore are digested in nitric acid, till nothing more is taken up.

(b.) Muriatic acid throws down 51 grs. of a white powder; boiling water redissolves 43, and 8 grs. of muriate of silver remain.

(c.) The solution in boiling water, by gentle evaporation, affords crystals of muriate of lead.

(d.) The residuum from the first step, (a.) is treated with nitro-muriatic acid, till nothing more is taken up; the solution is mixed with that remaining in (b.) and evaporated till no more crystals of muriate of lead are deposited; 11 grs. are thus obtained.

(e.) To this concentrated solution, caustic potash is added, in excess—a copious blackish brown precipitate falls; this is separated, and the alkaline liquor saturated with muriatic acid, when a white precipitate appears, which is redissolved in muriatic acid, and then precipitated by a stick of zinc; 85 grs. of tellurium are thus obtained.

(f.) The blackish brown precipitate is dissolved in nitro muriatic acid, and the liquor nearly saturated with caustic potash; nitrate of mercury is added, till the precipitate begins to whiten; this precipitate being filtered and washed, the filter, with its contents is ignited in a crucible; a little nitre is added, the fire increased, and a button of pure gold obtained, of 50.75 grains.

(g.) The remainder of the last nitro-muriatic solution is saturated with carbonate of potassa, and a precipitate obtained, of oxide of manganese, oxide of iron, carbonate of lime and alumina.

(h.) The insoluble residue of (d.) weighing 120.5 grs., is chiefly quartz; a gentle heat expels sulphur, 1 gr.: it is mixed with 4 parts of carbonate of potassa, and fused, and a button of silver is obtained, weighing 10.125 grs.*

There are two other varieties of ores of tellurium, one in which it is combined with bismuth, and in another, selenium is present.

IV. REDUCTION.

The dried oxide of tellurium is intimately mixed with 8 or 9 per cent of charcoal. The mixture being placed in a glass retort, the whole is gradually heated, to a low ignition; carbonic acid escapes, and some of the materials may pass into the receiver,† while

* As these analytical steps of Klaproth are short, I have preserved them, and the rather because there is reason to believe that the tellurium exists in this vicinity, at Monroe, Con.—For the analysis of the fourth sort, see Aikin's Dict. Vol. I. p. 411.

† For, if not cautiously managed, the decomposition is so rapid as to be almost explosive. This may be avoided by dissolving the purified oxide in muriatic acid, and precipitating the tellurium by a bar of iron; the black flocculi may be then washed and melted in a crucible.

a few *metallic globules appear in the neck*; the metal, with a bright crystalline surface, is found in the bottom of the retort; 100 parts of the oxide give 83 of the metal.

V. THE METAL—PROPERTIES.

• (a.) *Tin white, verging to lead grey; lustre, highly metallic; fracture foliated; brittle and easily pulverized; sp. gr. 6.115; by slow cooling, superficially crystallized; melts at about the fusing point of zinc, and is volatilized at ignition, being the most volatile metal, except osmium and quicksilver; in a curved tube, or a small retort, filled with nitrogen, it may be distilled over without change.*

(b.) *Before the blow-pipe, on charcoal, it inflames very rapidly, the flame is a vivid blue, with light green edges; a heavy white oxide rises, with a peculiar pungent and rather nauseous smell, usually compared to that of decayed horse radish, but which Berzelius attributes to selenium, and it is now said that the combustion of pure tellurium gives no such odor.*

(c.) *The oxide heated on charcoal is reduced, with a kind of explosion, and by combustion, it is again converted into an oxide which is stated to consist of metal 32, or 1 proportion, and oxygen 8=40, but these proportions need confirmation.*

(d.) *Heated in a glass retort, it fuses into a mass, which, on becoming cold, is of a straw color, and striated texture; the oxide, as already stated, is reduced, if heated in a retort in contact with carbonaceous matters.*

(e.) *Combines by fusion with its own weight of sulphur, and produces a lead colored, striated mass, with metallic lustre; a part of the sulphur sublims by ignition, and carries up some of the metal.*

(f.) *Sulphuric acid, without heat, takes up a little of the metal, and becomes colored, deep amethystine red;* the solution loses its color on the addition of water, and a black flocculent precipitate falls; heat also destroys the color, and separates a white oxide.*

(g.) *If the oxide be previously diluted with water, and a few drops of nitric acid added, a considerable portion of tellurium is taken up, the solution is colorless, and water does not decompose it.*

(h.) *The nitric solution is clear and limpid, giving slender prismatic crystals; the solution is not decomposable by water.*

(i.) *Muriatic acid has little action on tellurium; with a little nitric acid it gives a clear colorless solution; it is decomposed by water, and a white sub-muriate is thrown down; the precipitate, however, is resolvable in more water; alcohol separates the tellurium entirely from its solution.*

* If this fluid is exposed to the air, a sulphate of the oxide of tellurium is formed.
—H. and Ann. de Ch. et de Phys. T. XXXVII, p. 188.

(j.) *Hydrated oxide of tellurium is thrown down by alkalis, from all the acid solutions*; they and their carbonates, and all acids redissolve this precipitate. It is said to form salts, both with acids and alkalis.

(k.) Alkaline hydro-sulphurets throw down a black powder.

(l.) Prussiate of potassa produces no effect on pure telluric solutions.*

(m.) Tincture of galls gives a pale yellowish brown precipitate.

(n.) Tin, muriate of tin, antimony, zinc, iron, and phosphorus precipitate metallic tellurium.

(o.) The metal inflames in chlorine gas, and, by the addition of water, forms a white, semi-transparent compound, composed, according to Sir H. Davy, of tellurium 100+chlorine 90.5.—H.

VI. *POLARITY*.—*Electro positive*; it is attracted to the negative pole of the galvanic battery.

VII. COMPOUNDS OF TELLURIUM AND HYDROGEN.

1. *Hyduret of Tellurium*.—By using wires of tellurium as the means of communication through water, between the poles of a galvanic battery, a solid compound of tellurium and hydrogen is produced: it falls in the form of a brown powder, whose properties have not been investigated. It was discovered by Ritcher, in 1808, and was mentioned at p. 123, of this work.

2. *Telluretted Hydrogen*.—Discovered by Sir H. Davy, in 1809. An alloy of tellurium and potassium is formed by igniting a mixture of solid hydrate of potassa, charcoal, and tellurium, and to this is added dilute sulphuric acid. A peculiar gas is obtained, consisting of tellurium and hydrogen.

PROPERTIES.—Soluble in water, forms a solution of the color of claret, becoming brown by exposure to the air, and white tellurium is deposited. Smell resembles that of sulphuretted hydrogen, burns with a blue flame, depositing oxide of tellurium. It fugitively reddens litmus paper, and loses this property, on being washed with water. It unites with alkalis, precipitates the greater number of metallic solutions, and is instantly decomposed by chlorine. Composition, according to Berzelius, 100 metal, and nearly 2 hydrogen. Dr. Thomson calculates its sp. gr. at 2.2916.

VIII. *EQUIVALENT NUMBER*.—According to Berzelius, that of the metal is 32, and the oxide having one equivalent of oxygen, is of course 40; but it is observed by Dr. Turner, that these numbers, differing considerably from those of Klaproth, need confirmation.

* The solutions of this metal in acids are not decomposed by prussiate of potassa: gold, platinum, iridium, osmium, rhodium, and antimony, have the same property.

EX. MISCELLANEOUS.—This rare metal, hitherto almost peculiar to Transylvania, was announced by me ten years since,* as probably existing along with wolfram and other ores in the town of Monroe,† Conn. The evidence by chemical trials was stated, and it is little else than a recapitulation of the properties of tellurium described above. It might well have been expected that this interesting observation should have been, before this, either confirmed or annulled by me; but the shaft has not been wrought, and no more of the specimens have been placed in my possession. As the mine is now about to be explored, I still hope to have it in my power to establish the certainty.

Sec. XIX.—URANIUM.

I. DISCOVERY—NAME.—By Klaproth, 1789; named after οὐρανός,‡ the heavens.

II. NATURAL SOURCES.—*Obtained from its ores, viz.*

1. *Black uranium or pechblende.*§
2. *Micaceous uranium*—green oxide.
3. *Uranitic ochre.*

III. ANALYSIS.

(a.) The pechblende is commonly employed, and the contaminating substances being lead, iron, copper, sulphur, arsenic, cobalt, zinc, and silica are separated as follows.

(b.) The greater part of the ore is dissolved by digestion with moderately dilute nitric or nitro-muriatic acid; wash, dry, and ignite the residuum; sulphur is burnt off; digest with dilute nitric acid—the residue is silica.

(c.) To the nitric solutions and washings, add sulphate of soda till precipitation ceases; the precipitate is sulphate of lead.

(d.) Decompose the remaining solution at a boiling heat by caustic fixed alkali; digest the precipitate in caustic ammonia, till the copper is removed; slightly supersaturate this solution with sulphuric acid, and obtain metallic copper by iron or zinc, or as brown oxide, by caustic fixed alkali.

(e.) That part of the precipitate not taken up by the ammonia, is 2 or 3 times digested to dryness with nitric acid; then gently digest-

* Am. Jour. Vol. I, p. 406.

† A name since imposed; the distance of the mine from New Haven is nearly 20 miles west.

‡ The planet Herschell had been just named *uranus*, from the Greek οὐρανός, and in allusion to this name, and in compliance with the old alchemical custom of naming the metals after the planets, Mr. Klaproth denominated this metal *uranite*, at first, and afterwards *uranium*.

§ This is a mineral found in Saxony, about which very discordant opinions were entertained, till Klaproth examined it in 1789, and found it to consist of sulphur and a new metal.

ed in dilute nitric acid which takes up the uranium and leaves the iron oxide behind.

(f.) This nitrate of uranium being boiled with caustic fixed alkali, a pure yellow oxide of uranium is precipitated.

IV. REDUCTION.

1. Process.

(a.) 50 grs. of pure yellow oxide were, (by Klaproth), made up into a ball with wax, and placed in a crucible lined with charcoal and exposed for some hours to the action of a porcelain furnace, whose heat was estimated at 170° W.; a metallic button of 28 grs. was obtained.*

(b.) Arfwedson exposed the heated protoxide to the contact of hydrogen gas in a glass bulb; the matter became ignited, and the green color changed to reddish brown, with a crystalline structure and a metallic lustre, and was regarded as metallic uranium.

2. Process.—Sulphuretted hydrogen gas is passed through the neutral nitric solution, which precipitates the copper and lead; the excess of sulphuretted hydrogen is expelled by heat; the solution is decomposed by caustic ammonia, and the precipitate digested in strong carbonate of ammonia, which gives a lemon yellow solution; this solution, after a few days, deposits fine yellow prisms, consisting of uranium, carbonic acid, and ammonia, which, by ignition, are converted into protoxide;† or, the nitric solution may be set by to afford crystals of nitrate of uranium.‡

The uranium would be more easily obtained from the uran ochre, but this ore is so rare that it is hardly attainable for experiments.

V. THE METAL.

(a.) As obtained by Klaproth, it was of an iron gray color and metallic lustre, composed of hard minute grains, firmly adhering to one another. Sp. gr. 8.1. Internally, it is reddish brown; Bucholz obtained it of sp. gr. 9.; on being filed or rubbed with another hard body, the metallic lustre becomes iron gray; fusion very difficult.

(b.) It suffers no change under the blowpipe on charcoal, but it is said§ that when heated to redness in an open crucible, it undergoes a kind of combustion, becoming a grayish black powder containing about .5 oxygen; that obtained by hydrogen, on being heated, takes fire, swells, and is reconverted into green oxide.

(c.) According to Bucholz, it assumes shades of gray, violet, brown, green, orange and yellow, according to the degree of oxidization.

* See Thénard, 5th Ed. Vol. III, for the process with the *creuset brasqué*, viz. a crucible, lined with a mixture of powdered charcoal and moistened clay.

† Thomson's First Prin. Vol. II, p. 2.

‡ A more complicated process was practised by Arfwedson; see Ann. Phil. N. S. Vol. VII, p. 254, and Henry, 11th Ed. Vol. II, p. 69.

§ Nich. Dict. Art. Uranium.

(d.) According to Klaproth, *there are two oxides; the yellow or peroxide already mentioned, and the black or protoxide, obtained by heating the yellow oxide with oil and burning it off, from a test.*

(e.) In general, *the yellow oxide is obtained by the action of the acids, (especially nitric and nitro-muriatic,) on the ores, pure alkalis being used for the precipitation.*

It appears from the more recent researches of Arfwedson and Thomson,* that *the protoxide is obtained by heating the nitrate of the peroxide or the per-carbonate, when it is obtained of a dirty green; but it becomes a black mass with the particles coherent, provided it be ignited, after re-solution in an acid, and precipitation by ammonia. It is infusible, produces green salts with the acids; with the nitric passes to the condition of peroxide, and when redissolved forms a yellow solution.*

The peroxide is yellow, and forms salts of the same color; it unites both with acids and bases; from its solution in acids, it is precipitated by pure alkalis in the form of a yellow hydrate.

According to Dr. Thomson, the number 208 represents metallic uranium, and the protoxide is composed of metal 208 + oxygen 8=216;† the deutoxide consists of metal 208 + oxygen 16=224.

(f.) *Nitric acid is the only one that acts on this metal; nitric oxide gas is given out, and the metal is dissolved.*

(g.) *The yellow oxide is readily soluble in acids.*—Sulphuric acid, diluted and digested on it, gives a solution that affords, by evaporation, minute lemon yellow prisms.

(h.) *Diluted nitric acid readily dissolves this metal, and the evaporated solution affords large light green crystals in hexagonal tables.*

(i.) *Muriatic acid gives rhomboidal tables of a greenish yellow.*

(j.) *Phosphoric acid dissolves it, and the solution, after some time, deposits pale yellow flocculi, little soluble in water; they are phosphate or sub-phosphate.*

(k.) *Concentrated acetic acid, by digestion and evaporation, gives clear topaz yellow crystals—tetrahedral prisms terminated by tetrahedral pyramids.*

(l.) *Caustic alkali throws down a lemon yellow oxide from all these solutions.*

(m.) *Carbonated alkali gives a precipitate which is yellowish white, and is partly re-soluble in an excess of mild alkali; pure alkalis do not redissolve the oxide, but, after some time, change it to brown.*

(n.) *Prussiate of potassa gives a copious brown red precipitate, like kermes mineral.*

(o.) *Hydro-sulphuret of ammonia causes a brownish yellow precipitate.*

* Ann. of Phil. N. S. Vol. VII, and First Prin. Vol. II.

† Arfwedson places uranium at 216, and the oxygen in the two oxides at 1 and 1-2.

(p.) *Tincture or infusion of galls gives one of a copious brown, sparing at first, but abundant after the addition of an alkali.*

(q.) *The solutions are not altered by iron or zinc or other metals.*

(r.) *The yellow oxide, by heat, combines with sulphur into a mass of a deep brown, from which most of the sulphur is again expelled by an increased heat.*

(s.) *Nothing is known of the alloys of uranium.*

(t.) *Its oxide combines with vitrifiable matters, and imparts a brown or green color.**

(u.) *It strikes an orange yellow color, with the usual flux for porcelain, and has been employed in that manufacture.*

VI. POLARITY.—Probably like that of the other metals; I am not aware that it has been subjected to the battery.

VII. MISCELLANEOUS.—The uran mica appears from the experiments of Mr. R. Phillips, to consist of phosphoric acid and peroxide of uranium 73, phosphate of copper 12, and water 14, (Henry,) and Berzelius found similar ingredients in the yellow, substituting phosphate of lime for phosphate of copper. A native proto-sulphate of uranium, in green crystals, has been discovered by Dr. John, and sub-persulphate, investing some minerals with an intense yellow coating.†

Sec. XX.—TUNGSTEN.

I. DISCOVERY.—First indicated by Scheele; fully distinguished by the D'Elhuyarts.‡

1. Its ores are, 1. Tungsten or tungstate of lime. 2. Yellow oxide of tungsten. 3. Wolfram or tungstate of iron and manganese.

II. PROCESSES.

1. *The calcareous sub-species.*

(a.) Digest the pulverized mineral in 3 parts of moderately strong nitric acid; a part is dissolved and the remainder becomes of a yellow color; decant the acid solution; wash the residue and digest it in liquid ammonia; a portion is taken up, and the remainder becomes white; proceed, thus alternately, with nitric acid and ammonia, till generally nothing remains but a little silica.

* See Alkin, Vol. II, p. 455.

† Henry, 11th Ed.

‡ In a heavy Swedish mineral, of a dull white color, called tungsten, in allusion to its weight; in this, Mr. Scheele, in 1787, discovered what he supposed to be a peculiar acid combined with lime; he called it the tungstic acid.

By the Messrs. D'Elhuyarts of Spain, the same substance was afterwards found combined with iron, manganese, and tin, in a dark colored mineral called wolfram, which has since been found in Cornwall, and several other countries. From the tungstic acid, the D'Elhuyarts, by the aid of ignited charcoal, obtained a new metal.

In the United States, all the ores of tungsten are found at Monroe, Conn.

(b.) To the nitric solution, add liquid caustic ammonia, to separate oxide of iron and oxide of manganese; receive them on the filter; carbonate of soda added to the solution, precipitates the lime as carbonate, and its proportion may be ascertained in the usual manner.

(c.) The solution is now oxide of tungsten in ammonia; it is to be evaporated to dryness and ignited gently in a crucible; the ammonia is expelled, and yellow oxide of tungsten remains.

(d.) Or, fuse tungstate of lime, one part, with carbonate of potassa, four parts, dissolve in boiling water, twelve parts, and precipitate the tungstic oxide by nitric acid.

2. *Yellow oxide of tungsten.**

This is easily separated by liquid caustic ammonia, from the matters to which it adheres, and the expulsion of the ammonia by heat, leaves the oxide pure.

3. WOLFRAM.

(a.) Treat the pulverized ore, alternately, with nitro-muriatic acid and ammonia, till nothing but a few grs. of quartz remain.

(b.) The solution contains oxides of iron and manganese; it is mixed with perfectly neutralized carbonate of potassa, till the liquor begins to grow turbid; on being gently boiled, for a minute or two, a copious precipitate of oxide of iron takes place; the clear liquor, being neutralized with carbonate of potassa, deposits a cream colored precipitate of carbonated manganese, with a little oxide of iron.†

(c.) The ammoniacal solution contains the oxide of tungsten, which is obtained as already described.‡

(d.) Or, fuse wolfram, 1 part, with nitrate of potassa 3, and carbonate of potassa 2; dissolve in boiling water, and precipitate by nitric acid.§

(e.) Or, fuse powdered wolfram and 2 parts of carbonate of potassa; tungstate of potassa is formed, and with the addition of half its weight of muriate of ammonia, is dissolved in hot water. Tungstate of ammonia and muriate of potassa are formed. By desiccation and fusion, the muriate of ammonia is decomposed and expelled, and by solution in water, the black oxide of tungsten is separated. This is boiled with a weak solution of potassa and washed with distilled water.

This oxide, when heated in an open crucible, enters into combustion and becomes yellow tungstic acid.||

* This was first observed by me, among the ores from Monroe, Connecticut, where it is found in both the pulverulent and massive form. Am. Jour. Vol. IV, pp. 52, 187.

† For the mode of separating which, see Alkin's Dict. Art. Manganese.

‡ See some remarks by the Alkins on these analyses and their own; Dict. Vol. II, p. 444.

§ For other methods of forming tungstic oxide, see Thomson's Annals, VI, p. 198.

|| Henry, and Ann. de Chim. et de Phys. Vol. XXIX.

III. REDUCTION.

(a.) 100 grs. of the yellow oxide, being placed in a crucible lined with charcoal, and a strong heat applied for an hour and a half, produced a friable congeries of metallic globules, of the color and lustre of steel; weight 60 grains.

(b.) The yellow oxide, being mixed with oil, and heated two hours in the violent heat of a forge furnace, a darkish gray mass was obtained, consisting of a number of small metallic globules.

(c.) The oxide, mixed with oil and boracic acid, was heated as before, and gave a porous mass of a grayish white color; the cavities were lined with minute brilliant crystals.

(d.) 240 grs. of crystallized tungstate of ammonia, being heated for two hours in a charcoal crucible, by a powerful wind furnace, a slightly cohering mass was obtained, weighing 161 grs. and consisting of roundish bodies about as large as a pin's head, with a very brilliant metallic lustre.*

IV. THE METAL.

(a.) *Color, light steel gray; lustre, brilliant and metallic;* in minute grains, imperfectly agglutinated, brittle, hard, scarcely yields to the file; not magnetic.

(b.) *Sp. gr.* 17.6, (Elhuyarts); 17.33, (Aikin); 17.22, (Allen and Aikin); 17.4, (Bucholz); average 17.39, the heaviest substance known, except iridium, gold and platinum.

(c.) *Almost infusible*, (requiring at least 170° of W.); tarnished by heat and air, while an oxide is formed; oxygen gas, on charcoal, causes it to burn with a yellow flame, and it is volatilized in a thick vapor of yellow oxide.

(d.) *If we include the tungstic acid, there are two oxides of tungsten, the yellow and the blue,† or dark brown;* when the blue oxide is heated, it burns like tinder, being converted into the yellow oxide, which is the same that has been called tungstic acid. This last is stated by Bucholz, to be composed of oxygen 24, and metal 96; this latter number being the equivalent of the metal, and united with 3 proportions of oxygen $24=120$, the number for the acid. Dr. Thomson considers 126 to be the equivalent of tungsten, and with three proportions of oxygen, the oxide would correspond to 150. By others, 120 is assumed as the equivalent of tungsten. The brown oxide is supposed to be composed of tungsten 96, and 2 equivalents of oxygen $16=112$.

* See Nich. Jour. 4to. Vol. IV, p. 191.

† Its reduction is not so difficult as that of several metals, but its extreme infusibility prevents our obtaining it in considerable masses.

‡ See Aikin's Dict. Vol. II, p. 448.

(e.) *The metal is not dissolved by sulphuric, nitric or muriatic acid, nor even by boiling nitro-muriatic.**

(f.) According to Wöhler,† *there are three chlorides of tungsten*; the trito-chloride or per-chloride, of a white color, prepared by heating black oxide of tungsten in chlorine gas;‡ water resolves it into tungstic and muriatic acids;—the bi-chloride, obtained by heating the metal in chlorine; it takes fire and produces delicate needles of a red color;—and a third compound, formed along with the bi-chloride; it is of a fine red color, fusible and volatile.—*Murray.*

(g.) *The tungstic acid, as it has been called, is obtained by digesting muriatic or nitric acid on the ore*; adding ammonia to the residuum, and then neutralizing the alkali with nitric acid;§ a white powder is thus obtained; it is sour, reddening litmus; soluble in 20 parts of boiling water, and forms crystallizable compounds with alkalies.

(h.) *It is a triple compound of oxide of tungsten, and of the acid and alkali employed in the operation*; if it is boiled in a concentrated acid, it becomes yellow oxide of tungsten.

(i.) *This oxide has strictly but one acid property*; it is insoluble, tasteless, and without effect on vegetable blues; but it combines with the alkalies, as many other oxides do.

(j.) *The yellow oxide is obtained by heating the white powder mentioned under (g.)*; by digesting wolfram in nitric acid; dissolving the yellow remaining powder in ammonia; evaporating to dryness and expelling the ammonia by heat; also by fusing 2 parts of wolfram with 3 of nitre; by digestion in hot water, the potassa is combined with oxide of tungsten and oxide of manganese; the latter is precipitated by exposure to the air for a few days; the clear liquor, evaporated to dryness, is digested with 3 or 4 successive portions of nitric acid; the yellow oxide remains behind, perhaps combined with a little alkali.

(k.) *Yellow oxide, in a platinum spoon, acquires a deep green color under the blowpipe*; and

(l.) *On charcoal, becomes bluish black*;—dark colored when heated in a close crucible.

(m.) *The yellow oxide, digested with dilute muriate of tin, acquires a deep blue color*; the color is restored by warm dilute nitric acid, nitrous gas being given out; the blue is then a sub-oxide.

* The Atkins say, (Vol. II, p. 445, Dict.) that when a few drops of nitric acid are added, nitrous gas is liberated, and some of the metal is dissolved, and in part, diffused in the liquor as yellow oxide; the solution is not disturbed by water; prussiate of potassa gives a deep green; caustic potassa an olive brown, and the color is again restored by a few drops of nitric acid. † Ann. de Chim. et de Phys. XXIX, 43.

‡ There are appearances of combustion.

§ This simple but beautiful process, I have often performed upon both the calcareous and ferruginous tungsten of this vicinity; the other metals, iron, manganese, &c. are dissolved, and the tungstic oxide is left untouched, and is promptly dissolved by the ammonia.

(n.) *The yellow oxide is insoluble in acids, even when boiling; insoluble also in water; but, by rubbing with that fluid in a mortar, an emulsion is formed.*

(o.) *The yellow oxide is, by digestion with acetic acid, converted into the blue oxide, but is not dissolved.*

(p.) *The salts usually called tungstates, but which are really compounds of oxide of tungsten and an alkali, are formed thus.*

(q.) *Caustic potash, either by boiling or fusion, takes up the yellow oxide and forms a compound with excess of alkali; it is readily soluble, and by evaporation, affords a glittering powder; taste caustic and metallic; deliquescent.*

(r.) *This solution, super-saturated with nitric acid, throws down the white powder mentioned under (g.); boiled with lime water, it deposits a heavy powder like tungstate of lime; boiled with filings of zinc, tin or iron, the liquor becomes deep blue and affords* a similar precipitate.*

(s.) *Sulphuric acid, boiled on this white powder, changes it to blue, and the nitric and muriatic to yellow.*

(t.) *Remove the precipitate which lime water forms in the solution of this white powder, and the remaining liquor affords, on evaporation, crystals of nitre.*

(u.) *The compound of potassa with oxide of tungsten is decomposable by all acids, and the precipitate is always composed of the oxide, of the alkali, and acid.*

(v.) *Yellow oxide of tungsten, digested with carbonated alkali, causes effervescence, and a compound similar to the above is obtained.*

(w.) *With soda, it gives crystals, which are long hexahedral plates; taste acid, metallic and alkaline; soluble in 4 parts of cold and 2 of hot water; decomposed by acids; phosphoric acid however gives no precipitate, but forms a very soluble ternary compound, not decomposed by sulphuric acid.*

(x.) *Ammonia readily unites with the yellow oxide; the compound, after evaporation, crystallizes from its solution, in shining plates, like boracic acid, or in slender prisms; color, pale yellowish brown; taste, metallic; soluble, but not deliquescent; the alkali, when expelled by a red heat, leaves a yellow or blue oxide, according as the operation was performed in an open crucible, or in a retort.*

(y.) *It is asserted by Morveau,† that the triple acidulous tungstate, with infusions of turmeric and turnsol, forms colored lakes of great fixity.‡*

(z.) *No union with sulphur; alloys not known.*

POLARITY.—Supposed to be like that of the other metals.

* This fact occurs with all the triple salts of this oxide, if a few drops of muriatic acid are added.

† Ann. de Chim. Vol. XXX, p. 123.

‡ The Aikins say they have not answered well in England.

Remark.—The neutral tungstate of soda is unaltered by ignition in hydrogen gas ; the acid tungstate is converted into a compound of soda and oxide of tungsten which, when washed by water, becomes yellow like gold, and can be obtained, crystallized in cubes ; the tungstic acid, still retaining some alkali, affords metallic tungsten, when heated in contact with hydrogen gas.

For a notice of American ores of tungsten, see *Am. Jour.* Vol. I. The calcareous tungsten, and the wolfram exist, in considerable abundance at Monroe, Conn. and the wolfram takes on the form of the octahedron of the calcareous tungsten. Mr. C. U. Shepard thinks that these crystals are pseudomorphous, having copied the moulds of the other species.

The new species, which I observed some years since, the oxide of tungsten, is not abundant ; but it occurs, here and there, mixed with the other ores, and is found both pulverulent and massive.*

Sec. XXI.—MANGANESE.

I. ITS COMMON FORM.

1. The black oxide of this metal is familiarly known, and it is from this that the metal is extracted.

2. To obtain a pure oxide of manganese from the natural ore (which often contains carbonate of lime, and oxide of iron, besides copper and lead, and sometimes barytic minerals,) Mr. Faraday heats the black oxide in excess, with muriate of ammonia, projecting them, in separate portions, into an ignited crucible ; chlorine is of course evolved, and unites with the manganese in preference to any other substance, so that the chloride or muriate is pure, and being dissolved out by water, is decomposed by carbonate of potassa, and carbonate of manganese is thus obtained,† which, by ignition, gives pure oxide of manganese. Or, according to Mr. Hatchett, dissolve the black oxide of manganese in muriatic acid, and to the solution largely diluted, add ammonia ; the oxide of iron is precipitated, and by evaporation, and heating the residuum, to expel the muriate of ammonia, a pure oxide is left ;‡

3. Or, the brown oxide, left after oxygen gas has been obtained by the common process, is heated to whiteness for half an hour, in a covered crucible, with one sixth of charcoal powder ; it thus becomes a protoxide and is then dissolved in muriatic acid ; afterwards it is desiccated, fused and ignited, for a quarter of an hour, in seclusion

* I have been the more particular upon the ores of tungsten, because they occur in considerable abundance at Monroe, in this vicinity ; and I am informed by Prof. Torrey, that Wolfram has been found at the Cobalt mine, in Chatham, Conn.

† *Eng. Quar. Jour.* Vol. VI, p. 358.

‡ Dr. Torrey still found iron, after using Mr. Faraday's process.

from the air.* The resulting muriate or chloride, after solution in distilled water and filtration, contains no impurity except a little lime, which is removed by oxalate of potassa. Bi-carbonate of potassa or soda, being added to the solution, carbonate of manganese is precipitated; it isedulcorated and laid on a filter; the upper layer being rendered a little brown by the air, is removed, and the remaining white carbonate is kept in a vacuum along with sulphuric acid, until it is entirely dry; its solution in sulphuric acid will then be colorless, and all the salts of manganese may be prepared from it.†

3. NATIVE BLACK OXIDE OF MANGANESE is usually employed in chemical experiments.

(a.) *By ignition, it gives abundance of oxygen gas*, and becomes light brown. The experiment may be tried in a forge with a gun barrel.

(b.) It has been asserted that the brown oxide, by long exposure to the air, reabsorbs its oxygen.‡

(c.) *Ignited with charcoal, it gives gaseous oxide of carbon and carbonic acid.*

(d.) *Beautiful phenomena are exhibited, by its fusion in the following manner*, as I have many times seen with admiration.

If the black oxide of manganese be heated on charcoal with the blowpipe,§ and if a small piece of microcosmic salt, (phosphate of soda and ammonia,) or borax be added, a "bluish red pellucid glass" is formed, provided the interior blue flame of the blowpipe be directed upon it for a few moments; if the quantity of manganese be increased, the glass becomes of a rich red. Let it be again fused, but for a longer time, much gas will escape, and we shall find the tinge totally destroyed. This is owing to the disoxygenation of the oxide, by the charcoal, assisted by heat; if this now colorless globule, be softened by the exterior flame, the color quickly returns, and may again be discharged by continued fusion; this is owing to the reabsorption of oxygen from the air by the aid of a milder heat. The smallest particle of nitre, added to the colorless globule, will restore the color, because it imparts oxygen.

II. REDUCTION.

(a.) *Make a paste of the powdered black oxide, (or better of the purified oxide,) and lamp oil and charcoal, or pitch; form it into a ball; place it in a black lead crucible well lined with charcoal, and*

* The chlorides of iron, calcium, &c. are thus decomposed. It is now fully ascertained that muriate of lime is not unfrequently present in common black oxide of manganese, and that this is the source of the chlorine which has been repeatedly observed when the oxide is decomposed by sulphuric acid.

† Dr. Turner, 2d Ed. p. 447.

‡ This is a mistake according to Thomson and Aikin, (Vol. II, p. 64,) and according to my own experience.

§ Berg. II, 208.

heat it for three fourths of an hour or more, in a powerful air furnace.

(b.) Or, the carbonate thrown down from the nitric, or other acid solution, may be treated in the same manner.* Mr. Faraday obtained it by simply heating the tartrate alone, and by passing hydrogen gas over the heated oxide.

III. THE METAL.

(a.) Color, grayish white with some brilliancy; fracture granulated; hard as iron.

(b.) Sp. gr. 6.850 to 7; according to John 8.; brittle; does not melt below 160° W.; a slight attraction of the powder by the magnet is owing to iron.

(c.) Tarnishes rapidly in the air, and changes to gray, yellow, red, brown and black; more rapidly if heated in the air; becomes even incandescent, according to Black and Scheele.

(d.) Pour a white or light colored oxide into a bottle of oxygen gas, and it soon becomes black.

(e.) Decomposes water rapidly, evolving heat.

(f.) With diluted sulphuric acid, aided by heat, it gives hydrogen gas;

(g.) With nitric acid, nitrous gas; with the muriatic, hydrogen.

(h.) Chlorine inflames the metal.

IV. Number and constitution of the oxides of manganese.

Some of the most eminent chemists have investigated the oxides of manganese, but their opinions have not been entirely coincident, and it is not yet absolutely agreed how many oxides of this metal are to be admitted. *There are certainly three*; and some swell the number to five; without including the two acids of which manganese is supposed to be the basis. My own experience has made me acquainted only with the hydrated white, or protoxide; the brown or deutoxide; the black or peroxide; and with the combination, (the chameleon mineral) in which is found the acid, now called the manganic acid, but which was formerly supposed to be an oxide of manganese, dissolved by an alkali, and which, when in solution, easily changes its proportions of oxygen.

The history of the researches and opinions on this subject, involves more detail than is consistent with the nature of this work, and it possesses little interest, except in relation to chemical theory.

For a statement of the facts and reasoning, I therefore refer to Dr. Henry's Chemistry, Vol. II, p. 3, 11th Ed.† and to Dr. Turner's

* See Aikin, II, 61, for other particulars.

† Authorities quoted, LXXXVII Ann. de Chim. 149; Ann. de Chim. et de Phys. I, 39; Vol. V, 150; Vol. VI, 304, XX; Phil. Trans. Edin. 1828; Phil. Mag. July, 1828.

2d Ed. p. 444; and shall give only the conclusions expressed in the following table; but the most interesting facts will appear, in giving the history of the salts of manganese.

	Metal.	Oxy.	Metal.	Oxy.	Equiv.
Suboxide,	100	14.286	28	4	32
Protoxide, (green,)	100	28.572	28	8	36
Deutoxide, (brown,)	100	42.857	28	12	40
Tritoxide or } (black,)	100	57.144	28	16	44
Peroxide,					
Red oxide,	100	38.000	28	10.6	

It will be observed that, excepting in the red oxide, *the oxygen is in regular arithmetical proportion*, provided we admit a suboxide; if not, then, there appears to be a half proportion of oxygen between the protoxide and the deutoxide. This subject is not yet fully elucidated, and needs farther investigation. *The white oxide that is precipitated from acid solutions, is a hydrate.* The protoxide or green oxide is obtained by igniting the deutoxide in contact with hydrogen or charcoal, or by heating, in the same manner, the purified oxide or carbonate. It is *this* which, *alone, exists in solution in acids.* Its rich green color, on exposure to air, changes to brown. The brown or deutoxide remains, when the black oxide is heated to afford oxygen gas. This oxide is obtained also, by decomposing the nitrate of manganese, at ignition, in a platinum crucible. With the sulphuric and muriatic acids, it forms transient red solutions; the oxide being decomposed into the protoxide, which remains in solution, and the peroxide, which is precipitated. The tritoxide or peroxide of manganese is the common black oxide which, by heat, gives up half an equivalent of oxygen, and becomes deutoxide; but no heat, without the aid of combustible matter, can bring it to the condition of protoxide, and much less to the metallic state. It may be formed, artificially, by decomposing the nitrate of manganese, so as to destroy the acid, without expelling any oxygen from the oxide.

The red oxide of manganese, as it is termed, is formed by heating, to whiteness, the per- or deutoxide of manganese; when in powder, it has a brownish red color, and imparts to glass or borax a violet color; this oxide is regarded as a mixture of the protoxide and deutoxide; perhaps not a very probable supposition, since the color is constant.

V. ACTION OF ACIDS ON THE BLACK OXIDE OF MANGANESE; it is singular and instructive, and was first ascertained by Scheele, (*Essays*, p. 67,) and Bergman, (*Op. II*, 203); both authors are worthy of being read, and Mr. Scheele's Essay is a model of ingenious chemical analysis. He states four general conclusions, (p. 78,) drawn from his own experiments. I have translated the language of Mr. Scheele, from the terms of the phlogistic hypothesis, into those of the present theory.

1. *Black oxide of manganese, by means of its oxygen, is powerfully acted upon, by all combustible substances.*

2. *The presence of acids very much increases this action, by combining with the deoxidized manganese; thus the acids and combustibles mutually aid each other.*

3. *The oxide, by the action of combustibles, loses its black and assumes a white color, and the black color returns, when the oxygen is restored.*

4. *Without abstracting oxygen by combustibles, no colorless solution in acids can be formed, and in proportion as the oxygen is restored, the solution becomes blue or red.*

VI. SALTS OF MANGANESE.

1. Sulphate of manganese.

(a.) *The protoxide and the carbonate of manganese dissolve readily in sulphuric acid, of every density.*—The following is the usual process. Sulphuric acid, 6 parts, with black oxide of manganese 1, being ignited in a glass retort, much oxygen gas is disengaged and a white mass is obtained, which, by solution in boiling water, filtration, and the addition of a little sugar, affords a colorless fluid, and, by evaporation, large transparent rhomboidal crystals of sulphate of manganese.

(b.) *The first crystals have frequently a rose tint; the last are white; taste like that of sulphate of soda; soluble in $2\frac{1}{2}$ parts of cold water, but not in alcohol; composed of acid 40, being 1 equivalent, and 1 of protoxide of manganese, 36; also of 5 equivalents of water, 45, according to Mitscherlich.*—Turner.

(c.) *When sulphuric acid, in the cold, is added to black oxide of manganese, finely pulverized, a little of the oxide is dissolved, producing a red sulphate, and when water or an alkali is added to the solution, the red oxide is thrown down.*

(d.) Strong sulphuric acid also dissolves the deutoxide of manganese, but if diluted, it forms peroxide and sulphate of protoxide.

(e.) *Diluted sulphuric acid and a little oxide of manganese, with the addition of sugar, jelly, honey, &c. afford a colorless solution.*

2. *Sulphurous acid dissolves the peroxide, without addition, by attracting the excess of oxygen to form sulphuric acid; protoxide is left and the product is a sulphate.*

3. Nitrate of manganese.

(a.) *Nitric acid 1 oz. with 20 grs. of peroxide, and 1 dr. alcohol or spirits, being heated gently or placed in the sun's rays, nitric oxide gas rises, the oxide of manganese is dissolved, and then four more portions, of 20 grs. each, will be also dissolved.*

(b.) *Fuming nitrous acid dissolves the oxide without addition; the product is a nitrate; the nitric acid, in the sun's light, dissolves the oxide, because it is decomposed; nitrous acid is formed and thus the oxygen of the protoxide is removed.*

(c.) *The protoxide and white carbonate dissolve readily in nitric acid* and form a nitrate of the protoxide, which is very soluble, but crystals can be obtained from it. Its composition is, acid 1 equivalent, 54; protoxide 1, 36; and water 7, 63; =153.

4. *Muriate of manganese.*

(a.) *Muriatic acid, 3 or 4 parts, and 1 of the black oxide, with heat, give chlorine*; sugar or other combustibles, prevents the extrication of this gas, and in either case, a muriate results. The theory of the operation of muriatic acid upon black oxide of manganese has been already given; upon either the old or the new view, it is obvious, that muriatic acid ought to dissolve the black oxide, without the addition of combustible matter.

Concentrated muriate of manganese is rose red, and by slow evaporation, gives large transparent crystals, whose form is that of four sided tables. The muriate of manganese is most easily formed, by dissolving the carbonate in muriatic acid; *it is crystallized with difficulty*: it consists of acid, 1 equiv. 37; protoxide of manganese 1, 36; water 4, 36; =109.

5. *Chloride of manganese.*

(a.) *If the muriate is ignited, away from the air, it becomes a pink colored chloride.* Dr. Turner directs, that a current of muriatic acid gas should be passed over it, while it is heated by a spirit lamp in a glass tube: it is deliquescent, and by solution, becomes muriate of manganese. This chloride is composed of 1 equivalent of manganese 28; and 1 of chlorine 36.

(b.) The brown or deutoxide will also give chlorine with muriatic acid, but of course in smaller quantity.*

(c.) *Alkalies*, and especially carbonated alkalies, *throw down a white or brownish oxide* from these solutions; solution in acids will now take place without the addition of combustible matter.

(d.) *Caustic alkali is apt to give a brownish precipitate*, but if added to the solution of a concentrated sulphate or muriate, the precipitate is white; if diluted, it is brown.

(e.) *The precipitate grows darker by exposure to the air*; and is immediately blackened by agitation with oxygen gas.

* I once purchased a barrel of pulverized oxide of manganese, but was greatly disappointed in not being able to obtain from it a bubble of oxygen gas, by any process. Observing that it was of a brown color, it occurred to me that it had been already used to afford oxygen gas, and then saved and sold again. I was confirmed in this opinion, by finding that I could readily obtain chlorine from it both by muriatic acid, and by sulphuric acid, water and common salt, it being necessary only to use a larger quantity of the oxide. I have continued for more than twenty years, occasionally, to obtain chlorine by its aid, but it still refuses to afford any oxygen gas; a sufficient proof that *the brown oxide does not reabsorb oxygen from the air*.

It is hardly probable, that the native deutoxide, like that which is found, often in beautiful steel grey crystals, at Jhlefeld, in the Hartz, has found its way into the arts, which require the peroxide.

(f.) *Phosphorous acid dissolves the black oxide*; the rich red solution loses its color in a close phial, and re-acquires it by filtration in the air; nothing is separated, and these changes may be repeated, as often as we please.

(g.) *A new chloride of manganese has been formed*, by adding manganic acid to the sulphuric, and fused common salt to both; or, the chameleon mineral, in the green state, is converted into red by sulphuric acid; the evaporated fluid gives sulphate and manganesiate of potassa, and sulphuric acid evolves manganic acid from the mixture; fragments of common salt are added, as long as a colored vapor rises;* the theory is, in both cases, obvious; the oxygen of the manganic acid decomposes the muriatic acid, and the liberated chlorine unites with the manganese. This chloride is, at first, a vapor of a copper or greenish color, but, if passed through a glass tube at 5° or -4° , F. it becomes a brownish liquid, and if the tube be large, its vapor displaces the air. If poured into a large and moist flask, the contact with the moisture generates muriatic and manganic acids, the vapor of the latter having a red tint. From the fact that the elements of water are appropriated, and are equivalent to the production of the two acids, it is inferred, that this chloride is composed of metal, one equivalent, 28; and chlorine four, 144; = 172.

6. Fluoride of manganese.

(a.) *This name has been given to a compound, obtained by adding, in a platinum vessel, sulphuric acid to a mixture of the common chameleon mineral with half its weight of fluor spar.*

(b.) *It is a vapor of a greenish yellow, more intense than that of chlorine*, but by contact with the air, it becomes of a beautiful purple or red color.†

(c.) *It is absorbed by water, which becomes red*; attacks glass and forms fluo-silicic and manganic acids; *decomposes dry chloride of calcium, evolving heat and pure chlorine.*

(d.) Its composition is supposed to be 1 equivalent of manganese, and four of fluorine.‡

VII. CHAMELEON MINERAL.§

Fuse, in a crucible, 1 part of pulverised black oxide of manganese, and 3 parts of nitre; the nitric acid is decomposed and expelled by the heat; and the alkali unites with the manganese, now become an acid: *a dry greenish or blackish mass remains which is partly soluble in water.*

* Turner, 2d Ed. 451, and Edin. Jour. No. XV, p. 179.

† It is a beautiful experiment.—J. T.

‡ Ann. de Chim. et de Phys. Jan. 1828, and Henry and Turner. These experiments lend great weight to the opinion that fluorine is a distinct principle, and if the chloride of calcium, decomposed by this fluoride, is truly a chloride and not a muriate, it affords an example of the separation of chlorine from a base, by a simple exertion of affinity, without implying the decomposition of muriatic acid, and must therefore, tend greatly to fortify the present views of the nature of chlorine.

§ Discovered by Scheele.

The same compound is produced, by fusing 1* part of oxide of manganese with 5 or 6 of caustic potash, or carbonate. This solution has at first, a green color, which would appear blue; but, the preparation being usually made from the black native oxide, which always contains oxide of iron, this was formerly supposed to give, by its yellow color, a greenish tinge to the blue. If the green solution of the common oxide be kept a few days† in a close vessel, the yellow oxide of iron then precipitates by degrees, and the solution appears blue. If this blue solution be exposed to the air, or if a large quantity of water, or an acid‡ or hot water§ be added, the solution assumes a violet color, then red, then brown, and lastly, the black oxide of manganese is separated and falls, and the liquor becomes colorless. These changes were formerly imputed to the absorption of oxygen from the air; or, from that dissolved in the water, which was supposed to give the oxide of manganese a color continually deepening, till finally it is all precipitated. A few drops of a solution of any sulphuret, or of sulphuretted hydrogen, sulphurous acid or chlorine, destroy this play of colors immediately. The compound has, on account of its changeable colors, acquired the fanciful name of *chameleon mineral*. It may be formed with baryta, strontia or soda.

NEW VIEWS OF THE CHAMELEON MINERAL.

Manganetic and manganeseous acid.

(a.) If this compound be formed, by fusing together in a crucible, one part of pure oxide of manganese, with eight of pure potassa, the same play of colors is exhibited, which proves that it does not depend upon iron, but upon the absorption of oxygen.

(b.) It is now admitted, that *the chameleon mineral is a definite compound of manganese, in the acid form, with potassa*; that it is not formed, if the materials are heated in a vessel filled with nitrogen, that oxygen may be absorbed in the process of forming it, and that it may be obtained *in regular prismatic crystals of a purple color*. They detonate with phosphorus, and set fire to sulphur, arsenic, antimony, and other combustible bodies.

(c.) *The acid is called the manganetic.*

(d.) This acid has been obtained in a free state, by heating nitrate of baryta with peroxide of manganese, and the acid, thus generated, is separated by saturating the baryta with sulphuric acid, when the manganetic acid makes its appearance, in the form of a rich red fluid.

* Equal parts, (Laugier, Cours de Chimie) some thousandth parts of the oxide will impart to the mass, melted with potash, the power to tinge the water of the solution green. † Scheele, Essays, p. 107. ‡ Id. and Berg. II, p. 224.

§ Two glasses, one with hot and one with cold water exhibit very strikingly the different degrees of rapidity and intensity in the production of the colors. Excess of acid, and of alkali, alternately, change the color to red and green.

(e.) It is supposed that *there is also another acid with a smaller proportion of oxygen; it is called the manganeseous, and it is believed that the changes of color in the chameleon mineral are owing to transitions between the two saline conditions* ;* substances that attract away oxygen, as alcohol and carbonate of manganese, change the red or manganesiate of potassa to the green or manganesite; the acid, in the latter, being supposed to contain three equivalents of oxygen, and that in the former, four.†

(f.) It is obvious, that if *these views are correct, the present explanation of the phenomena of the chameleon mineral accords, very nearly, with the old opinion of the absorption of oxygen, and there will be, at least, five or six distinct degrees of oxygenation of manganese*.‡

VIII. ACTION OF AMMONIA.—By passing this gas through tubes of iron, or of earthen ware, containing ignited black oxide of manganese, we obtain red vapor of nitrous acid; but, as I have observed, sometimes mixed with white fumes of nitrate of ammonia, and then the red fumes disappear and nitric oxide gas is extricated; for, only the nitric portion of the acid combines with the ammonia.

The hydrogen of the ammonia, with part of the oxygen of the oxide, forms water, while another portion of oxygen, with some of the nitrogen of the ammonia, forms nitrous acid.§

IX. EARTHS.

(a.) *They do not combine with metallic manganese, but readily with the oxide, which imparts to them a red, purple or violet color.*

(b.) Hence, used in coloring glass and porcelain, as already stated, giving chiefly red and violet colors.

(c.) Black oxide of manganese discharges color from glass, especially the yellow and green, caused by iron; and also the dark hues, derived from combustibles. It imparts oxygen—every thing combustible is burnt, and the iron, by a high oxidation, becomes less visible, while the black oxide of manganese, by losing oxygen, becomes colorless and invisible. Too much manganese renders the glass purple or red; and if too little is added, some of the other tints remain. On account of its power of rendering glass colorless, the black oxide of manganese was *formerly called by the artists, glass maker's soap*.

* Ann. de Chim. et de Phys. IV, p. 287; VIII, p. 337. Ann. of Philos. XVI, p. 130, containing the researches of Chevillot, Edwards and Forchhammer.

† The portion of oxygen is not considered as settled with certainty.

‡ Prof. Laugier (Cours de Chim. T. II. p. 74.) suggests a doubt whether the oxygen, alternately acquired and detached, passes to the alkali, or to the manganese, or to both: he regards the question as undecided, as to the cause of the difference of color, between the "*two chameleons*."

§ The French are said to have manufactured nitre for gun powder, during the revolution, by forming nitric acid in this manner. Black, II, p. 455.

X. SULPHURET OF MANGANESE cannot be formed, by heating the metal and sulphur together, but the proto-sulphate, by being ignited in a charcoal crucible, was converted into a sulphuret, of an iron gray color and crystalline aspect; it consists of 1 proportion of sulphur and 1 of metal.

Solutions of manganese, although not precipitated by sulphuretted hydrogen, are decomposed by hydro-sulphurets, and thus a sulphuret of manganese may be formed.* There is a native bi-sulphuret found in Cornwall, and in Transylvania.

XI. THE ALLOYS OF MANGANESE are little known. It is often found combined with iron, and some such ores afford the best steel.

XII. POLARITY.—*Electro positive*, (from analogy,) I am not aware that it has been ascertained by experiment.

XIII. USES.—Employed, by the potters, to give the black color to earthen ware, besides the dark, violet, and purple already mentioned; formerly used in the ornamental figures on Delft, and most other kinds of earthen ware; and on the tiles, used in the past age, in decorating chimnies.

Indispensable in the modern practice of bleaching, and in chemistry, as it affords large quantities of oxygen, and produces chlorine at a cheap rate.†

Sec. XXII.—ARSENIC.

I. HISTORY AND NAME.—*In some of its combinations, long known.* The *συνδραραχη*, of the Greeks, was a sulphuret, which was afterwards called *αρσενικον*; the word *αρσενικον* is more modern.—*Thomson.*

II. NATURAL HISTORY.

(a.) *Arsenic*, (sometimes alloyed with other metals, especially with cobalt and iron,) is *occasionally found native*.‡ It is a *heavy dark mineral*, and when it has a structure in scales or plates, it is called *testaceous arsenic*.

(b.) *The native sulphuret forms two minerals*; the one of a lemon yellow, sometimes inclining to green, and called *orpiment*;§ the other of a ruby red, and frequently crystallized, in brilliant needles or prisms; the latter is called *realgar*—it is a proto-sulphuret; it is

* For other methods of forming the sulphuret, see Ann. of Phil. N. S. VII, p. 330, and Henry, 11th Ed. Vol. II, p. 14.

† Its black oxide is often found with iron ores, and is sometimes mistaken for them. It happened, a few years since, in New England, that large quantities of this ore, (as from the effects, we are justified in concluding,) were used in a powerful iron furnace. The fuel is said to have burned with the greatest intensity, with a vast column of flame, and a roaring so unusual as to terrify the workmen, and they were astonished to find no iron, but only a slag in its stead.—*Private communication to the author.*

‡ In Bohemia, Hungary, Saxony, and especially at St. Marie aux Mines in Alsatia. Berg. II, p. 283.

§ Called now a sesqui-sulphuret.

found at Vesuvius, and both are found in Hungary and Germany. The orpiment and realgar of commerce are, principally, artificial productions.

(c.) *Also extensively diffused among the ores of other metals* ;* especially in those of cobalt ; not unfrequently in those of iron, copper and silver, and sometimes in those of lead, tin and antimony.

(d.) *The native oxide is rare*, and is usually found, as an efflorescence, on native arsenic.

The white arsenic of the shops is an oxide or rather an acid ; it is formed and collected in the chambers attached to the furnaces for smelting lead, copper, and tin ores, and in the roasting of white pyrites, and especially of nickel and cobalt ores in Saxony, in the manufacture of zaffre and smalt.† It is sublimed in winding horizontal chimnies, where it forms a crust or coating.

III. WHITE OXIDE OR ARSENIUS ACID.—PROPERTIES.

(a.) *Shining and vitreous* ; sometimes semi-transparent, or of an opaque white, inclining to yellow. It is powdery when first sublimed, and it obtains the vitreous appearance by a new sublimation, with several hundred pounds at a time, in large iron matrasses.

(b.) *As it feebly reddens the vegetable blues*,‡ and possesses some of the other acid properties, it is now often called arsenious acid.

(c.) *Taste commonly said to be very acrid, but at last, sweetish*. Dr. Turner avers, from personal observation, that the taste, if deliberately observed, is only that of faint sweetness or acidity and that a majority of persons perceive no taste.

(d.) *Smell alliaceous, if in contact with ignited charcoal, but from a hot body which is not combustible, it rises in a white cloud, without odor*.

(e.) *Soluble in water*, but authors differ as to the degree ; the experiments of greatest authority, (those of Klaproth and Bucholz,) give its solubility at $77\frac{1}{2}$ of oxide of arsenic to 1000 of water at 212° ; or about 1 part in 13 ; while at 60° , the same quantity of water dissolves only 2.5 parts, or 1 part in 400 of water ; the solution made at 212° by growing cold, deposits more than half, or 47.5 parts out of 75.5. Fischer§ says, that the white oxide of arsenic is insoluble in water, and becomes so only in consequence of a transfer of oxygen from one part of the arsenic to another, which thus becomes acidified and soluble, while the remainder takes the form of an insoluble yel-

* It is exceedingly troublesome in metallurgic operations ; it is immediately recognized by the alliaceous or garlic odor, which it evolves, on being heated or struck. *Arsenpickel* is a compound of sulphur, arsenic and iron ; there is also an arseniuret of iron without the sulphur.

† Black, II, p. 427.

‡ As is seen when the powder is placed on moistened litmus paper ; especially when that which is transparent is used.

§ Thom. Ann. VII, p. 33.

low powder. He states the solubility at 1 part in 12.3 of boiling water, and 1 in $66\frac{1}{2}$ of cold.

(f.) *Soluble also in oils, and in from 70 to 80 parts of alcohol.*

(g.) *By slow sublimation, it crystallizes in regular transparent octahedra; at 283° F. (Th.); or 380° , (Henry,) this oxide sublimes, and if heated suddenly in close vessels, it becomes pellucid like glass; but on exposure to the air, it recovers its former appearance. The glass has the sp. gr. of 5; the common oxide, and the crystallized, that of 3.7. (Aikin.)*

(h.) *Composition—75.2 arsenic, and 24.8 oxygen.—Proust.*

Other chemists agree pretty nearly with the view, that it is composed of arsenic, 100 parts, oxygen 33.33; or per 100, 75 arsenic to 25 oxygen.

According to Dr. Thomson, it is composed of arsenic, 1 propor. 38; and oxygen two, =16; =54, its equivalent; which gives 71 arsenic to 29 oxygen.

According to Berzelius, its composition is 1 equiv. of arsenic, 36; + $1\frac{1}{2}$ or 12 oxygen; =50.

(i.) *It combines with bases and forms arsenites; they are produced, by boiling it with the bases in water.*

IV. REDUCTION.

(a.) *One part of the white oxide, in powder, is mixed with 2 or 3 of black flux, (procured from the detonation of 1 part of nitre with 2 of tartar,) and the mixture is placed in a crucible coated with sand and clay, and luted to another, which is inverted over it like a dome, and is protected from the heat, by a plate of iron with a hole, in which the lower crucible hangs. A red heat, applied to the lower crucible, then causes the metallic arsenic to sublime, and it is found adhering to the upper crucible in a crystalline form.*

(b.) *The reduction is also easily effected in a Florence flask or Cologne-water vial, luted at the lower part with sand and clay, and ignited in an earthen table furnace, the upper part of the vial or flask being inclined out of the heat, and loosely stopped with a coil of paper.**

(c.) *In the large way, powdered oxide of arsenic is distilled with charcoal dust, iron filings and lime; the carbon detaches the oxygen, and the iron and lime detain the sulphur, if any is present; a similar theory may be given of the first experiment. Arsenical pyrites, ground fine, are sometimes substituted for the oxide of arsenic, and the distillation is performed in earthen retorts coated with a fire lute.† Gray's Op. Chem. p. 748.*

* All operations upon arsenic, by heat, should be performed under a well drawing vent, otherwise the operator will be, seriously, in danger.

† Dr. Hare's notice of the mode of obtaining Arsenic.—Arsenic is sold in commerce under the name of cobalt. As it is very attractive of oxygen, and in the state,

(d.) For greater purity, the metal is dissolved in nitro-muriatic acid, precipitated by a plate of zinc and resublimed.

(e.) *The polarity of arsenic being, like that of the other metals, electro positive*, it is evolved at the negative pole, when the white oxide is galvanized, and if the wire be copper, it will be whitened.

V. THE METAL.—*Properties.*

(a.) *Very brittle, easily pulverized in a mortar, and forms a black powder: the recent fracture is brilliant; color bluish*, between that of tin and lead; the newly sublimed metal resembles polished steel, and is crystalline in its structure.

(b.) *It soon tarnishes in the air, becoming sometimes iridescent at its surface*, and ultimately dull and black; but, under pure water, preserves its lustre.

(c.) *Sp. gr. 8.310. Harder than copper*, but neither ductile nor malleable; evolves a peculiar smell when handled.

(d.) *On burning coals, a red hot iron or any ignited body, it takes fire, burns with a blue and whitish flame, an offensive odor of garlic peculiar to this metal,* and is converted into the white oxide.*

(e.) *It is the most volatile of all the metals; it scarcely melts† before it flies off in vapor, and if, with the exclusion of air, the arsenic is recovered without change.*

(f.) *This metal, spontaneously, absorbs oxygen from the air, and is converted into a voluminous black powder: Berzelius found that in three months, 100 parts became 108.*

VI. ARSENIURETTED HYDROGEN.

1. PROCESS.

(a.) *Obtained by boiling muriatic acid upon the metal*, when it dissolves some of it, it rises in gas, and acquires the smell and poisonous qualities of arsenic.

in which it bears this name, is full of crevices, it is so much tarnished, or blackened, by oxidization, both internally and externally, that it is not possible, even by a fresh fracture, to see the true color or lustre of the metal.

In order to attain this object in perfection, the cobalt, (as it is absurdly named,) should be pulverized coarsely, and introduced into a glass tube sealed at one end. The tube should be less than half full. Thus prepared, it should be placed within a cylinder of iron, closed at the base. The but-end of a gun barrel will answer. The space between the iron and the glass should be filled with sand, and another gun barrel applied, so as to catch any fumes which may arise, and conduct them into a chimney. That portion of the glass tube which contains the arsenic, should be kept red hot for about an half hour. After the apparatus is quite cool, the metal will be found in crystals of great splendor, occupying that portion of the glass tube, which is above the part heated to redness.

According to Thénard, arsenic may be sublimed in a glass retort, filled with nitrogen, and heated by a spirit lamp.

Dr. Torrey uses an oil flask, over a naked charcoal fire, and then divides the flask in the middle by a hot ring.

* It is stated by some, that powdered zinc, thrown on burning coals, produces a similar odor, (Turner, 2d Ed. p. 467.); but I cannot think that this smell belongs to the zinc, as I have, in a multitude of instances, burned it in this manner, without perceiving any such effect, and if it has ever been observed, it is probably owing to the presence of arsenic. † It can be melted, under pressure, and then it can be cast in ingots.

(b.) *Also, this gas is obtained, by adding arsenic or its oxide to the mixture of sulphuric acid, zinc and water; or, by digesting an alloy of tin 3, and arsenic 1, in muriatic acid.*

(c.) *Or, by the alloy of arsenic, potassium and antimony, formed by heating strongly for two hours in a close crucible, two parts of antimony, two of cream of tartar, and one of white oxide of arsenic. If 2 or 3 drachms of this alloy be thrown under a jar, inverted in water, this gas is abundantly disengaged.**

2. PROPERTIES.

(a.) *A permanent elastic fluid; very fetid; and extremely dangerous to respire.†*

(b.) *Sp. gr. 52,‡ air being 100; 4 cubic inches contain 1 gr. of arsenic; it varies, owing to the mixture with hydrogen.*

(c.) *Hostile to combustion; eminently combustible; burns, from a jet, in oxygen gas, with great splendor; detonates with atmospheric air, depositing arsenic, and with oxygen gas, oxide of arsenic.*

(d.) *Chlorine precipitates the arsenic, by uniting with the hydrogen; not absorbable by water, and not acid; dissolved by a solution of sulphate of copper.*

(e.) *Composition; 3 volumes of hydrogen with 1 volume of vapor of metallic arsenic, condensed into 2 volumes.*

(f.) *By galvanizing water, the negative pole being pointed with arsenic, and also by acting on water with an alloy of potassium and arsenic, a solid compound of this metal and hydrogen is generated; it appears in the form of a brown powder or of flocculi, and much more hydrogen is evolved than usual.*

VII. *SULPHUR, by fusion, unites readily with arsenic or with the metal of its oxide, and forms two sulphurets, the red and the yellow, both of which exist also as natural productions.*

(a.) *It is now agreed, that the difference between the red and the yellow sulphuret depends upon the proportions of the principles.*

(b.) *Realgar, or the red sulphuret, contains arsenic 1 propor. or 38, + sulphur 1 propor. or 16 = 54; and orpiment, 1 propor. or 38; + sulphur 1½ propor. or 24; = 62.*

(c.) *The orpiment is, therefore, what is called a sesqui-sulphuret; that is, it has an equivalent and an half of sulphur. It is possible, however, that there may be another sulphuret with a smaller proportion of sulphur, which will hereafter remove the fractional expression.§*

* Eng. Quar. Jour. XIII, 225.

† M. Gehlen, after nine days of convulsions and extreme suffering, was destroyed, by respiring a very small quantity of it.—Ann. de Chim. XCV, 110, and Ann. de Chim. et de Phys. III, 185.

‡ 55. Davy.

§ Bergman says, (II, 287,) that yellow or red compounds are produced, "according to the different proportion." Dr. Hope, (note book,) states, that one tenth sulphur to 1 white oxide, produces orpiment, and one fifth of sulphur produces realgar. By this union, the activity of the arsenic is greatly repressed, and its poisonous quali-

(d.) *Orpiment may be formed in the humid way.*—To the white oxide of arsenic, dissolved in muriatic acid, add an aqueous solution of sulphuretted hydrogen, and there is a fine yellow precipitate, or, the sulphuretted hydrogen gas may be passed through a solution of white oxide of arsenic.

(e.) *In the arts, realgar is produced, by distilling in earthen retorts,* from $3\frac{1}{2}$ to 5 parts of white oxide of arsenic with 1 of sulphur, or a mixture of arsenical pyrites with iron pyrites; it is afterwards melted over again, skimmed and cast in iron moulds.*

(f.) *Orpiment† is made in a similar manner, by distilling a mixture of arsenical pyrites that has long been exposed to the air, with one tenth of their weight of iron pyrites, or by using $7\frac{1}{2}$ to 9 parts of white arsenic with one of sulphur, or $3\frac{1}{2}$ cwt. of arsenic with $\frac{1}{2}$ cwt. of sulphur.‡*

(g.) *Under the name of king's yellow, orpiment is used as a paint, and it has been recommended as a dye for silk.*—Melt, nearly at ignition, in a crucible, 1 part sulphur, 2 arsenic, and 5 potassa of commerce; dissolve in hot water and filter; dilute, and, by sulphuric acid, precipitate a superb yellow; dissolve in ammonia added in excess; immerse the goods; they come out colorless, but become yellow as the ammonia evaporates.§

(h.) *In calico printing, the blue indigo is brought to the condition of green, by the action of orpiment, which attracts away oxygen.*

(i.) *The sulphurets of arsenic are poisonous, but considerably less so than the oxide.*

(j.) If sulphuretted hydrogen gas be passed through a solution of arsenic acid, or of arseniate of potassa or soda, adding some muriatic or acetic acid, the hydrogen of the gas and the oxygen of the arsenic acid unite, and the sulphur with the metal forms a per-sulphuret. It resembles orpiment, but contains two equivalents of sulphur and 1 of metal.—Turner.

VIII. PHOSPHORUS unites with arsenic, by heating them in equal parts beneath water, in a flask or in a close vial; the phosphuret of arsenic is black, and ought to be preserved under water or alcohol.

IX. CHLORINE GAS, warm and dry, spontaneously inflames arsenic and produces a proto-chloride.

ties are diminished, in so much that in China and other eastern countries, they employ, as a purgative, lemon juice, which has stood some hours in a cup made of realgar. Black, II, 426.

* Coated with a mixture of clay, iron filings, blood, hair and alum.

† It would seem that these two sulphurets can be converted into each other by a particular management of the heat. Nothing more being necessary to convert orpiment into realgar, than to expose it to a strong heat; and with the same mixture, we may, at pleasure, obtain either of these products, according to the manner of applying the heat.—Chaptal.

‡ Gray's Op. Chem. p. 749.

§ Henry, II, 57, and Ann. de Chim. et de Phys. XII, 98. Alkalies affect the color, but acids do not.

It may be formed, also, by distilling 6 parts of corrosive sublimate and 1 of metallic arsenic. It is a colorless fuming fluid, which, by the action of water, is converted into muriatic and arsenious acids.

With an excess of chlorine, a white crystallized matter appears, which is probably a perchloride. The opinion of chemists as to these chlorides is not exactly settled.*

X. IODINE *in excess*, unites with arsenic by the aid of heat; the compound is of a deep red, and by the action of water, produces the hydriodic and arsenic acids.

XI. BROMINE, by mere contact, burns metallic arsenic, with vivid light and heat; the bromide is volatile, and water converts it into oxide of arsenic, and hydro-bromic acid.

XII. ACIDS.—Arsenic hardly unites with the acids to form salts, like most of the other metals.

(a.) By being repeatedly boiled on arsenic, sulphuric acid is decomposed; sulphurous acid is disengaged and arsenious acid formed.

(b.) The nitric acid acts with violence on the powder of arsenic; nitrous gas is evolved, and arsenic acid produced; it also converts the white oxide into the arsenic acid.

XIII. SALTS.

(a.) When chlorate of potassa and arsenic, 3 of the salt to 1 of the metal, pulverized separately, and mingled by a feather, are struck on an anvil with a hammer, they detonate with violence. This mixture takes fire, from contact with a burning coal, or with sulphuric acid. It flashes like lightning, and the contrast between it and gun powder is strikingly seen, if a train of this mixture is fired at the same time with one of gun powder.

(b.) Nitrate of potassa, heated with arsenic or its oxide, burns it, and converts it into the arsenic acid.

XIV.—ALKALIES.

(a.) No action between them and the metal, but they unite with the white oxide, producing arsenites.

(b.) This union is easily effected by heat, or by boiling.

(c.) The arsenites have been but little examined; those of the alkalis are soluble and uncrystallizable; those of the earths are of difficult solution, but are easily dissolved in an excess of their own acid; also in nitric acid, and in other acids with which their bases do not form insoluble compounds; the other arsenites of the metals are formed, by mingling an alkaline arsenite with a solution of the metallic salt.

The arsenite of potassa, formerly called Fowler's solution, is employed in medicine, and is made according to the directions of the pharmacopeia, by boiling together, in 1 pint of water, powdered oxide of arsenic and carbonate of potassa, of each 64 grains, till the arsenic

* See Henry, 11th ed. Vol. II, p. 57, and Dumas, Ann. de Chim. et de Phys. LXXXVI, p. 360.

is dissolved ; when cold, four fluid drachms of the compound spirit of lavender are added, and distilled water enough to make one pint.*

XV.—EARTHS.

The white oxide readily unites with them.—It is employed, in glass making, to destroy color, and to increase transparency ; but in larger proportion to produce a milky opacity, and along with the oxides of tin and lead to form a white enamel, such as is seen in watch faces.†

XVI.—METALS.

Arsenic unites with most of the metals. It renders the malleable metals brittle, the refractory more fusible, and the fusible more refractory ; the yellow and red are whitened, and the white become grey.‡ All the alloys are decomposed by heat.

XVII.—ARSENIC ACID.

1. DISCOVERY—By Scheele.

2. PROCESS.

Powdered white arsenic 2 parts, in a tubulated retort, *with 7 of muriatic acid* ; dissolve with gentle ebullition ; promptly *add 3½ oz. of nitric acid*, returning into the retort the acid which passes into the receiver ; heat the retort again, and when the fumes of nitric oxide gas cease, add another ounce of white oxide and apply heat ; this being dissolved, add 1½ oz. more of nitrous acid, and distil to dryness, and even to ignition, when the arsenic acid will form a white mass, to obtain which,|| the retort may be broken, or the acid may be dissolved in distilled water.

3. THEORY.—*The dissolved oxide receives one proportion of oxygen from the nitric acid*, and thus becomes arsenic acid.

4. COMPOSITION.—1 proportion of arsenic, 38 ; + 3 of oxygen, 24 ; = 62, its equivalent number ; while the white oxide, or arsenious acid has but two proportions of oxygen, and its equivalent number is 54.§

Thus, the constitution of these acids resembles that of the sulphurous and sulphuric.—H.

5. PROPERTIES.

(a.) *Very fixed in the fire ; it even vitrifies at a very high heat*, and attacks earthen and glass vessels ; it also gives out a little oxygen gas, and becomes in part white oxide.

(b.) *This acid is very poisonous ; more so than the white oxide.*

* Dose, 2 to 15 drops, once, twice, or thrice a day ; it may be gradually increased, as Dr. Coxe states from his own experience, to 80 drops, three times a day.

† This enamel was formerly used to glaze the Delft ware, and it was twisted in beautiful scrolls in the stalks of wine glasses.—Black Vol. II, p. 425.

‡ Tin excepted, which by this means acquires a permanent and shining whiteness, and by fusion is able to retain half its own weight ; nor does arsenic spoil the color of platinum.

|| Scheele's Essays, p. 144.

§ Berzelius is of the opinion that the oxygen in the arsenious and the arsenic acid, is as 3 to 5.

(c.) *Sp. gr. 3.391*; it reddens vegetable blues, and is deliquescent.

(d.) *Soluble, very slowly, in six parts of cold water, but almost instantly in 2 parts at 212°*; it even remains in solution, although a considerable part of the water is evaporated. With half its weight of water, it has the consistency of syrup; and, by farther evaporation, becomes gelatinous, and deposits grains rather than crystals.

(e.) *Taste, extremely acid, caustic, and metallic.*

(f.) *Decomposed by the simple combustibles*, which attract its oxygen, and leave either the oxide or metallic arsenic.

(g.) *With charcoal powder, at ignition, there is a violent combustion*, and metallic arsenic is liberated.*

(h.) Sulphur 1 part + acid 6; at the melting point of sulphur, there is a violent combination, the whole mass rises in a red sublimate, and sulphurous acid is formed.†

(i.) *Heated with phosphorus, phosphuret of arsenic and phosphoric acid are produced.*

(j.) *The more combustible metals are oxidized by the oxygen of the arsenic acid*, and it even inflames some of them.‡

(k.) *Metallic arsenic, with heat, divides the oxygen*, and both are converted into white oxide.

(l.) *Iron filings, 1 part, being distilled with 4 of arsenic acid*, the iron burns, and both white and metallic arsenic are sublimed.

(m.) *One part of tin filings, and two of arsenic acid takes fire in the same manner*, and with the same result.

(n.) *One part of zinc filings, with two parts of dry acid of arsenic, by ignition, produced a violent inflammation*, and the retort burst. In the neck were found metallic arsenic and sublimed oxide of zinc.

(o.) *In combination with bases*; the arsenic acid§ forms arseniates.||

General characters of Arseniates.

1. The alkaline arseniates, soluble in water—the rest only sparingly, but becomes more so by an excess of acid.

2. Like the phosphates, dissolved and decomposed, without effervescence, in diluted nitric acid and many other acids.¶

3. Precipitated, unchanged, by pure ammonia.

4. Most of them sustain ignition without decomposition; but, ignited with charcoal, they afford metallic arsenic; those of the common metals, as lead and copper, are easily reduced in a glass tube; the rest require a higher heat.

* Scheele's Essays, p. 150.

† Id.

‡ An. de Chim. et de Phys. XIX.

§ It effervesces with the carbonates; like the phosphates, the arseniates, although neutral in solution, crystallize with an excess of base.

|| For a particular account of which, see Fourcroy and Thomsen.

¶ Those are excepted which precipitate the base of the salt.

5. Soluble arseniates, detected by the tests for arsenic, and the insoluble, after being decomposed by boiling with alkaline carbonates, —the excess of alkali being previously saturated by nitric acid.

6. Those of lime, nickel, cobalt, iron, copper, and lead, are natural productions. (Dr. Turner.)

1. ARSENIATE AND BINARSENIATE OF POTASSA.

(a.) *The neutral arseniate does not crystallize*, but with a slight excess of acid, affords fine crystals.*

(b.) *They are rectangular prisms of four sides*, terminated by very short four-sided pyramids.

(c.) *Soluble in 5 parts of water*, but insoluble in alcohol.

(d.) COMPOSITION.—*Arsenic acid*, 2 proportions, 124; *potassa*, one, 48; *water*, one, 9;=181.

The famous ague drops are a solution of this salt.†

(e.) *From the arseniate of potassa the arsenic acid may be obtained in purity.* It is decomposed by acetate of lead, and the arseniate of lead by sulphuric acid, digested upon it for two hours; the arsenic acid is liberated, and may be obtained, concrete, by the aid of heat.

(f.) *Arsenate of soda crystallizes like phosphate of soda*; effloresces in a dry air; taste cooling; soluble in four parts of water; suffers the aqueous fusion.

(g.) COMPOSITION.—1 equivalent of soda, 1 of acid, and 8 of water. There is also a binarsenate of soda with 2 equivalents of acid, 1 of base and 5 of water.—*Henry*.

The other arseniates present nothing particularly interesting.

(h.) *The salts, with a strong heat, are decomposed by the arsenic acid*, not excepting the sulphate of baryta; and the fluates and muriates are also decomposed in the same manner.

It will be remembered, that there are three vitrifiable acids, namely, the phosphoric, the boracic, and the arsenic; which, in consequence of their sustaining the heat‡ without volatilization, and of their tendency to vitrify along with bases, produce decompositions, which would not be effected by their force of attraction merely. It is said, that there is a great analogy between the arseniates and the phosphates, and that the corresponding salts are analogous in composition, and identical in form.§

* Identical with Maquer's neutral arsenical salt, (Scheele, 152,) which is commonly produced, by heating equal parts of nitre and white arsenic in a crucible, when the oxygen of the nitric acid acidifies the oxide of arsenic, which combines, in excess, with the alkali, and produces a super or binarsenate of potassa.

† (Accum.) from one-sixteenth to one-eighth of a grain of the crystallized salt is a dose;—it is used in remitting fever; in periodical headach; in dropsy, and in elephantiasis. (Murray, Mat. Med. I. 169.) For similar purposes the arsenical solution of Fowler, composed of white oxide of arsenic and potassa, has been used. See p. 187.

‡ The remark in the text is true only in a qualified degree with respect to the phosphoric, which, when pure, can be volatilized. See Vol. I. p. 424.

§ Vide Scheele's Essays.

XVIII. DETECTION OF ARSENIC, WHEN USED AS A POISON OR taken accidentally.

The white oxide of arsenic is a frequent instrument of death.

It is usually taken, either in food or medicine, and the victim is smitten with agony, before he is aware of danger.

The white oxide of arsenic is moderately soluble in a variety of fluids, especially in hot water, but more commonly it is mixed with other white powders, as sugar, flour, magnesia, &c. In such cases, the points to be attended to are, commonly, these.

1. *The symptoms before, and the appearance after death.**

2. *The properties of certain powders or drugs, believed to have been mixed with the food or medicine; or during life, rejected from the alimentary canal;† or, detected in it after death.*

The symptoms before, and the appearances after death, being similar to those which result from some other violent diseases, are not entirely to be trusted; and we must resort to a faithful examination, without which we can form no certain conclusion; and to determine whether a substance presented is arsenic, an accurate acquaintance with the properties of this metal is indispensable.

1. If it be arsenic it will, if placed on hot iron, wholly evaporate, in white fumes; but so will corrosive sublimate and some other substances.

2. If placed on live coals, it will not only sublime, but, at the same time, unlike other sublimates, emit a distinct smell of garlic, which is so characteristic, that if the arsenic is unmixed, there is no chance of mistake; but, when the odor is mixed with that of animal and vegetable matter, it is sometimes so disguised, that this trial is not decisive.

3. If ever so small a quantity of it be mixed with three times its weight of black flux, in a glass tube, coated with fire lute, and placed among live coals, or even naked, over the flame of a spirit lamp, it is reduced, and metallic arsenic coats the tube within, with an opaque but shining crust.‡

* "The symptoms produced by a dangerous dose of arsenic begin to appear in a quarter of an hour, or not much longer, after it is taken. First, sickness, and great distress at the stomach, soon followed by thirst and burning heat in the bowels. Then come on violent vomiting and severe colic pains, and excessive and painful purging. This brings on faintings, with cold sweats, and other signs of great debility. To this succeed painful cramps, and contractions of the legs and thighs, and extreme weakness and death.

After death, the intestines are found inflamed and corroded; and sometimes inflammations and erosions of the anus happen before death."—*Dr. Black.*

† Animals are effectually poisoned by inserting arsenic in cuts made even in the extremities; it is said that the stomach is, in such cases, affected, as if the poison had been received into that cavity.

‡ Push a wire through the mixture so as to open a channel, near one side of the tube, for the vapors to escape; but this is unnecessary, provided the black flux is thoroughly dried before it is used.

4. *The metallic arsenic, thus obtained, takes fire, if thrown on a red hot iron; and sublimates in the form of white oxide; and in both cases with the garlic odor.*

5. The minutest particles kindle in chlorine gas.*

6. If the tube be clean and dry, that part containing the newly evolved metallic arsenic, may be held a little above the flame of a spirit lamp, when the metal will slowly sublime, and become again oxide of arsenic, condensing in distinct and peculiar crystals. Dr. Black, (II. 430,) from one grain of white oxide obtained, in a small tube, enough of the metal to enable him to perform all the other experiments.†

The reduction of the arsenic is perfectly decisive, and if this proof is obtained there can be no mistake. There are however other trials that are useful auxiliaries.

1. File two cents bright, or clean them with nitric acid, or take two pieces of sheet copper an inch square, hammer them into a form a little concave, and place in the cavity a mixture of the substance with black flux; bind them together with wires, and give them a dull red heat, for a few minutes, among the coals: on removing the wires, the copper will be found to be whitened, so as to resemble lead or tin; whereas, this degree of heat would completely dissipate mercury, or any other substance, capable of whitening the copper.

2. I am not disposed to multiply uncertain tests for arsenic, and shall therefore mention to the student only those which, if they do not decisively direct, may seriously aid the judgment.‡

(a.) *Sulphuretted hydrogen appears to be one of the most important tests of arsenic.* If, to an arsenical solution, a saturated watery solution of this gas be added, there is a golden yellow precipitate. A stream of the gas is said to be still better, but any excess of it should be expelled by boiling, as it suspends the precipitate, and it is

* A striking experiment before a class.—J. T.

† I have repeatedly obtained satisfactory results with one-fourth of a grain of white oxide; and by operating in a very small tube over a spirit lamp and with extreme care, I have succeeded with one-tenth of a grain, and have no doubt that even half that quantity might answer. We are recently informed that Prof. Berzelius finds that 1-100th part of a grain is sufficient. Dry charcoal and dry pearlashes may be substituted for black flux; charcoal alone would decompose the oxide, but it might be volatilized before decomposition, which is prevented by the base of the alkali, operating by its affinity for the arsenic, and this would be still more important, if the subject of experiment were the sulphuret of arsenic.

‡ A full table of the effects of various chemical tests on arsenic, dissolved in water and various fluids, may be found in Dr. Coxe's Dispensatory, (Ed. 1825, p. 114.) I am of the opinion, that the principal use of tests is in aiding the judgment of the chemist; and that before a court and jury, nothing will or ought, in such cases, to prevail for the condemnation of an accused person, short of the production of the metal itself. This accords, at least, with my own experience in such trials, and I have found it useful to exhibit in court, tubes, in which arsenic, known to be such, had been reduced, some in fractions of grains, and in others in grains, in order to show both the nature and certainty of the evidence. In cases of poisoning by arsenic, satisfactory evidence can almost always be obtained, provided proper care is, seasonably, taken, in preserving and examining every thing, that might create a suspicion.

necessary, in both cases, that the arsenical solution should be slightly acidulated with acetic or muriatic acid, because the yellow precipitate is soluble in excess of alkali. This test is also applicable to arsenic, when mixed with animal and vegetable fluids, provided they are previously boiled, filtered, and acidulated.

(b.) *The only uncertainty to which this test is liable, is, that it produces a similar precipitate with selenium, cadmium, tin and antimony;* but it is not difficult to distinguish the sulphuret of arsenic from that of any of these substances, because, by heating it with black flux,* we can, in the ways already described,† obtain the metal from it, and cause it to give the alliaceous odor, and, by a little dexterity in managing the heat of the lamp applied to the part of the tube containing the metal, it may be reconverted into white arsenic, which will even crystallize in beautiful octahedra. Dr. Turner thinks this test is decidedly preferable to any other.

3. *Chromate of potassa.*—This valuable test was introduced by Dr. Thomas Cooper, President of the College of South Carolina.

(a.) *The yellow solution of chromate of potassa is turned green in half an hour, by the arsenious acid, or oxide;* I have often observed the change to take place, within 10 or 15 minutes; it is owing to a transfer of oxygen to the arsenic, and the chromic acid is thus changed into chromic oxide, the proper color of which is green. If, on the addition of ammonia, the color does not become blue, we are certain that it is not copper. Dr. C. confides in this test to detect $\frac{1}{32}$ of a grain of arsenic, whether in powder or in solution. For the benefit of contrast, and of diversified proof, Dr. C. recommends to take 5 watch glasses, and upon Nos. 1, 2, and 3 to place, in succession, solution of arsenic, of arseniate of potassa, and white oxide in substance; upon 4, some drops of solution of corrosive sublimate, and upon 5, of copper; then add to each, a few drops of chromate of potassa; in half an hour, Nos. 1, 2, and 3 will exhibit a bright grass green, unchangeable by ammonia—No. 4 will give an orange precipitate, and No. 5 a green, which ammonia will convert to blue.‡ Dr. Henry is the only European author, so far as I have seen, who has noticed this test, which appears to be one of the best that we possess.

4. *Bergman's test, or Scheele's green.*

(a.) *To the supposed arsenical solution, a few drops of a weak solution of carbonate of potassa are added, and then a little of the so-*

* It is observed by Dr. Turner, that while carbon is the active principle in reducing the oxide of arsenic, the alkali is chiefly operative in decomposing the sulphuret; its potassium unites with the sulphur, and liberates the arsenic.

† See Dr. Christison in Edin. Med. and Surg. Jour. Oct. 1824, and Vol. II, Trans. Med. Ch. Soc. Edin.

‡ Am. Jour. Vol. IV, p. 160.

lution of sulphate of copper, free from iron; if arsenic be present, there will be a precipitate of a grass green, which will be rendered more striking, by comparing it with one obtained from sulphate of copper by fixed alkali, without arsenic, which will be blue; and also with one obtained, by the same means, from a known solution of arsenic.

(b.) This experiment is well performed, by using with the arsenical solution, an ammoniacal solution of copper, made by decomposing sulphate of copper by ammonia, till it ceases to dissolve any thing more; it will give the same result as the other tests. It will be proper to confirm these experiments, by trying the grass green precipitate on burning coals for the alliaceous odor, and with black flux for the metal.

(c.) On the whole, this test is a good one, and when applied to arsenic in solution in pure water, is scarcely liable to any fallacy, but with some animal and vegetable infusions, it gives a color similar to that of Scheele's green, although no arsenic is present, and that arsenic may be suspended in small quantities in tea and porter, and other mixed fluids, without being discovered by Bergman's test, because there are affinities between the arsenic and the vegetable principles; for instance, a free acid or tannin, or perhaps some of the animal principles.*

5. Nitrate of silver.—Much has been said of this test, as introduced by Mr. Hume, and modified by Mr. Sylvester, Dr. Marcet, and others, but there are so many conditions attached to its use, and it is liable to so many ambiguities, that I do not think it worth while to recite them.†

The best form appears to be to decompose nitrate of silver, by ammonia, which will dissolve the oxide and we should stop when there is some of the oxide remaining undissolved; this insures us against an excess of ammonia. *If this solution is dropped into one of arsenic, a yellow arsenite of silver is precipitated*, the ammonia going into union with the nitric acid; phosphate of silver, that might be formed from soluble phosphates present in the fluid, is dissolved by the ammonia, so as not to interfere with the arsenical precipitate of silver, and as the ammonia just saturates the nitric acid, it will not dissolve the arsenite of silver. Still, the presence of the muriates, or of animal and vegetable infusions, may prevent the arsenite of silver from precipitating, or from exhibiting its peculiar color.

* This is stated to be the fact with a strong infusion of onions, in which alkali and sulphate of copper are said to produce a precipitate like Scheele's green; but this is imputed to the medium—the green hydrate of copper being seen through the brown color produced by the action of alkali on the vegetable infusion.—Murray, Elem. Vol. II. p. 243.

† See Dr. Henry, Dr. Turner, and Mr. Murray.

6. *Lime water, added in excess to a solution of arsenious acid, produces a white precipitate of arsenite of lime, (Dr. Turner,) but the precipitate scarcely appears in an oleaginous or gelatinous fluid, and seems to be of little value unless the arsenite can be obtained dry, and unless metallic arsenic can be made to appear upon it by heating it in a glass tube, with black flux by a spirit lamp.*

There are other objections to this test, and it appears to possess no peculiar advantages.

7. The iodide of potassium or hydriodate of potassa has been proposed by Prof. Emmet as a test for arsenic.*

It produces a white precipitate both with the arsenites and with arsenious acid. This precipitate is changed to brown, purple, or black, by strong nitric acid. Sulphuric acid produces the same effect if aided by heat, and a bright yellow in the cold, and strong muriatic acid gives the same color.†

Where arsenic is mingled with the contents of the stomach, the whole should be evaporated to dryness at a heat below that of boiling water, and then digested with strong nitric acid, which at once dissipates the organic matter and leaves the poison in the state of arsenic acid; a similar result is obtained by deflagration with nitrate of potassa, and the tests can then be applied.‡

For additional particulars respecting the discovery of arsenic, and the treatment both before and after death, the reader may consult Orfila's work on poisons, and Ure's Dict. 2d edition.

It is stated that such is the antiseptic power of arsenic, that the whole body has been preserved by it, and the stomach and intestines have remained firm and entire to periods extending from five to thirty months, and in some of these cases the poison has been even discovered.§

XVIII. USES—DANGERS—REMEDIES.

(a.) *In substance|| and in solution, especially in the form of arsenite and arseniate of potassa, much used in very small doses in intermittent fevers.*

* See Am. Journal of Science, Vol. XVIII. p. 58.

† Brugnatelli uses recent starch of wheat thickened by boiling; iodine is added till it is blue, and then water until it is azure, when an aqueous solution of arsenic changes it to reddish hue and finally discharges the color. Solution of corrosive sublimate produces similar changes, but sulphuric acid more than restores the blue color, which it fails to do in the case of arsenic.

‡ Dr. Hare prefers the nitrate of silver.

§ Edin. Phil. Jour. VIII. 381, quoted by Prof. J. W. Webster in his Manual.

|| Oxide of arsenic 2 grs. powdered opium, 8, castile soap, 22, formed into a mass, and divided in 32 pills, U. S. Phar. or 1 gr. arsenic, 10 sugar, and bread enough to form 10 pills, of which 1 is a dose.

(b.) *By the Orientals*, said to be used *for the poison* of venomous animals, and

(c.) *By Europeans*, externally to cure ulcers and cancers.

(d.) *At first an empirical remedy*; afterwards adopted, to a degree, by the faculty; 10 grs. of the white oxide are dissolved in 1 oz. of water, and it is applied with a pencil. Arsenical remedies must, however, be used with caution, as they sometimes affect the whole system.*

In cases of poisoning by arsenic, it should be evacuated if possible, by a mild and quick emetic and cathartic, as white vitriol and Glauber's salts. It is usual to give abundance of milk and oil.† Copious draughts of warm water and mucilaginous drinks are thought to be preferable.

Aqueous solution of sulphuretted hydrogen and alkaline sulphurets, mitigate the poison, if in solution, but, they are not often in readiness, and they scarcely affect the arsenic in substance.

When the dose is not fatal, it commonly entails on the sufferer, extreme debility and irritability, both general, and of the intestinal canal; and paralysis, with a ruined constitution, is the usual result.

These effects are produced even upon miners, who are much employed among the fumes of arsenic.

It appears that intermittent fevers, formerly arising from the marshes, have ceased in Cornwall, since the copper smelting works have been established, and the impression of the workmen is, that the fumes kill all fevers. It is said that in Cornwall and Wales, horses and cows within reach of the fumes loose their hoofs, and the cows are sometimes seen crawling about on their knees, have a cancerous affection in their rumps, and that the milch cows loose their milk. The miners and smelters use sweet oil as their antidote, and it is kept constantly provided for them.‡

(e.) *In glass making*, to aid in discharging color; in producing white enamel and white figures on porcelain, and in a modern imitation of porcelain; large quantities of arsenic are used in the Boston glass manufactories, and it has now become an object to roast the numerous arsenical ores of this country for the extraction of the arsenic.

* Murray's Mat. Med. I. 374.

† Doubts however are entertained of the propriety of this practice, as the acid of the arsenic may coagulate the milk, and the oil has been thought to favor its action. Murray's Mat. Med. I. 170, and Bl. II. 130.

‡ Coxe's Dispens.

XXIII. COBALT.

I. HISTORY.—*Employed in Europe, as early as the fifteenth century for the purpose of tinging glass blue*; but the minerals used for that purpose were not known to contain a peculiar metal till it was discovered by Mr. Brandt, a Swedish chemist, A. D. 1733. Many chemists have since added to our knowledge.

II. PROPERTIES.

(a.) *Color, steel gray, or if pure, nearly tin white; when tarnished it has a tinge of red; dull, like cast iron; structure, usually granular, sometimes laminated or fibrous.*

(b.) *Brittle, and easily pulverized; hard; nearly without taste and smell.*

(c.) *Melts at a degree of heat not under 130° of W. and requires more heat than cast iron; by slow cooling, it crystallizes in irregular prisms.*

(d.) Sp. gr. 8.538.

(e.) *It does not evaporate with any heat.*

(f.) *Magnetic, but inferior in energy to iron; a magnetic needle has been made from it, (H.) Its magnetism was formerly attributed to iron; but it is magnetic, when purified from every trace of that metal.*

III. RELATION TO OXYGEN.

1. Combustibility.

(a.) *Slowly oxidized by heat and air, and becomes a blue oxide; deepening until it is nearly black, and an intense heat melts it into a black blue glass.**

(b.) *In the focus of the compound blow-pipe, it even burns, brilliantly, with a rich red or purple flame, and the oxide rises in the current of hot air.*

2. There are two oxides of this metal.

(a.) *The protoxide is formed, by strong heat, and free access of air, as just described; and from the muriate or nitrate of the protoxide,† it is precipitated by potassa or soda, in the form of a blue hydrate, it is properly of an ash gray color, although the cobaltic salts, in which it exists, are generally of a pink hue.*

(b.) *The peroxide is black; it is formed by exposing the protoxide to the air, from which, especially when aided by ignition, it rapidly absorbs oxygen, and becomes first, olive green, and ultimately black; this oxide exists on some of the cobalt ores.*

(c.) *By a stronger heat (a cherry red continued for half an hour,) oxygen is expelled, and it is reduced to protoxide.*

The peroxide cannot combine with acids, or produce a blue color in glass and fluxes, until by losing oxygen, it has become protoxide.

* Four. V 195.

† The acids unite only with the protoxide of this metal.

(d.) *Composition of the oxides.*—Not yet exactly settled. Thomson places the equivalent of the metal at 26, and Rothoff* at 30; according to the latter, the oxygen in the protoxide is to that in the peroxide as 1 : 1.5 or as 2 : 3, and if 30 be admitted as the equivalent of the metal, that of the protoxide will be 38, and of the peroxide 42.†

IV. COMBUSTIBLES.

(a.) *The sulphuret may be formed directly by fusion*, but it is not easy to succeed.

(b.) *By heating the metal with an alkaline sulphuret.*

(c.) *Color, yellowish white*, displays the rudiments of crystals, and is with difficulty decomposed by heat.

2. *The phosphuret is formed,*

(a.) By throwing phosphorus on the ignited metal.

(b.) Or, by heating cobalt, in contact with the vitreous phosphoric acid and charcoal.‡

(c.) It is whitish and brittle; more fusible than the metal; becomes tarnished by the air and loses its phosphorus by heat, while the cobalt is oxidated.

V. *Chlorine gas burns the fine powder of cobalt* producing a white flame; and a chloride, little known, is the result.

VI. ACIDS.—All the acids attack either cobalt or its oxide.

1. *The strong sulphuric, with ebullition, oxidates and dissolves the metal*; sulphurous acid gas is evolved and a reddish colored salt§ formed. The oxide is dissolved, without decomposing the acid. The crystals are acicular rhomboidal prisms, soluble in 24 parts of water.

2. The NITRIC ACID *dissolves this metal*, with effervescence of nitric oxide gas.

(a.) *Arrangement.*||—Metal 1 part, acid 5 or 6, placed in a flask over a lamp, till dissolved; leave it at rest, and then decant the fluid; evaporate to one half the volume and obtain crystals; at or near saturation, the solution has a brown rose color or a bright green. It is from the nitrate that the oxide of cobalt is usually precipitated for enamel and porcelain.¶

(b.) *The nitrate of cobalt is decomposed by heat, and leaves a deep red powder.*—Potassa precipitates it blue, which, in a close vessel, becomes violet and red, and is soluble in cold carbonate of potassa. Cobaltic solutions are precipitated by carbonated alkalies, first peach-flower red, and afterwards lilac. (H.)

* Ann. Philos. III. 356.

† It is agreed however, that the subject needs further investigation.

‡ Four, V, p. 197.

§ According to Dr. Thomson it is a bisulphate.

|| Accum, II, p. 35.

¶ Four. V. p. 199.

3. *The muriatic acid scarcely affects the metal, but readily dissolves the oxide.*

(a.) *The nitro-muriatic acid acts upon the metal with energy, and the result is muriate of cobalt.*

(b.) *It is easily formed, by dissolving oxide of cobalt in muriatic acid; if the peroxide is used, the excess of oxygen will cause the disengagement of chlorine.*

(c.) *The muriate of cobalt does not crystallize: the concentrated solution is blue;* when diluted it is rose red.*

4. *Sympathetic ink.*—This name has been given to certain metallic solutions, which, in a diluted state, are so nearly colorless, that we can write or draw on paper, without having the traces visible. The solutions of cobalt are very liable to change color when heated, and the muriate is the most remarkable.

(a.) *It is usually prepared from the nitrate, as follows. Digest cobalt, 1 part, and nitric acid 4, and when the solution is finished, add 1 part muriate of soda and 16 of water. It thus becomes a muriate of cobalt.*

(b.) *Nitrate of cobalt† is easily made by dissolving 1 part of zaffre in 2 of diluted nitric acid.*

This solution, if pure, is, when concentrated, of a fine blue, although owing to iron it is usually green, but, when largely diluted, it is pale rose red or pink. Writing, done on a clean paper with this ink is invisible in the cold, but, by a gentle heat, assumes a beautiful pea green color, or blue, if no iron is present; in either case, it loses color as it cools, and thus it may be made, alternately, to appear and disappear, many times, in succession. Paper fire screens are sometimes adorned by drawings of trees, whose trunks and leafless branches, are sketched in India ink or other appropriate colors, (a winter scene,) and the foliage is made with the invisible solution of cobalt; on bringing it near to the fire, the green leaves at once appear, (and spring returns.)‡

(c.) *A blue sympathetic ink is formed, by saturating acetic acid or vinegar with oxide of cobalt, and adding $\frac{1}{2}$ of common salt.*

* Sometimes green from the presence of iron.

† The oxide of cobalt, being made for the arts, can be obtained from London; I find this the most convenient substance for preparing the cobaltic salts, and the sympathetic ink is made from it, merely by dissolving it in muriatic acid, without any addition except water to dilute it. Zaffre can be obtained in New York, and answers very well for sympathetic ink; if it is dissolved in nitro-muriatic acid, it needs nothing but the requisite dilution. Smalt, I find, does not give up its cobalt to acids, and sympathetic ink cannot be made from it.

‡ The usual theory has been, that moisture dissolves and renders the cobaltic salt invisible; drying causes it to appear, and steam or the breath, or even the vapor of the air, to disappear. But the changes of color sometimes happen in the fluid itself, (Murray); and the effects take place, even if the paper be enclosed in a bottle and this immersed in hot water; the color fades, as the water cools, and returns when it is heated, (Fourcroy); therefore it is supposed that it is not moisture only, but that it is owing to different states of oxygenation; the subject is still to a degree obscure.

(d.) *A greenish yellow ink*, is produced, by adding a little nitrate of copper to the muriate of cobalt, and also a little muriate of soda or of magnesia or lime; both these inks are to be used like the muriate of cobalt, always observing not to heat the paper too much, lest it should be corroded and the color fixed.

5. *Probably all the acids would dissolve the oxide of cobalt* and form peculiar salts; but they are not sufficiently important to be named.

It may be worthy of remark that *phosphate of soda and muriate of cobalt give a lilac precipitate*, which being mixed with 8 parts of fresh precipitated alumina and dried, forms a blue pigment that may be substituted for ultramarine.*

Oxalic acid gives, with cobaltic solutions, a rose colored precipitate; prussiate of potassa a grass green; borax a pink, and hydrosulphuret of ammonia a black.

VII. THE ALKALIES *have no action on the metal*; they are employed to precipitate its oxides from solutions in acids, and they readily dissolve them; ammonia dissolves zaffer and gives a fluid of a beautiful red color.

VIII. THE SALTS.

(a.) *At a high temperature, the nitrates burn this metal*, without detonation or flame, and convert it into an oxide; and the oxide of cobalt is thus prepared for enamels, pottery and porcelain.†

(b.) *Chlorate of potassa*, 3 parts, and cobalt, in powder, by percussion, produce detonation.

IX. EARTHS.

(a.) *No action with cobalt*; a very interesting one with its oxide, especially in the case of *silex*, to which the oxide, by fusion, imparts a rich blue color, sometimes with a shade of purple.

(b.) *Borax is commonly used for the detection of cobalt*; by fusion with this salt, the characteristic blue color is instantly produced, and if the shade is too deep to be observed, it must be diluted with more borax and melted again. *When, however, iron greatly predominates*, as in some of the arsenical cobalt ores, *borax does not acquire the blue color*, but rather a greenish or reddish hue, and the iron must be first removed before borax will answer in the usual manner.‡

* Henry, and Eng. Quart. Jour. XV, 381. This pigment is called *cobalt blue*, in the shops; by means of the blow-pipe, it is easily distinguished from the real ultramarine: the spurious color turns black by the application of heat.—J. T.

† Four. V, 202.

‡ Prof. Dana in Am. Jour. Vol. VIII. p. 302. In the arsenical cobalt ore of Franconia, New Hampshire, there is so much iron that the borax does not acquire from it the blue color, and yet its presence is demonstrated by roasting the mineral, dissolving it in nitric acid, evaporating to dryness and dissolving again, and evaporating to separate the peroxide of iron; now a peach colored deposit is observed, and this, dissolved by a globule of ignited borax, imparts to it the blue color. The nitric solution of this mineral, treated with common salt, gave the rose colored sympathetic ink, which became green by heat.

(c.) *Zaffre is oxide of cobalt, mixed with pulverized flint.* It is prepared in Saxony* by roasting the arsenical cobalt in an oven-shaped reverberatory, the flame of wood playing on the ore, and the arsenical fumes are condensed in layers; in a square, winding, or zig-zag horizontal box or chimney of boards, sometimes six hundred feet long; the odor of the arsenic is sometimes perceived at the other end.† The oxide of cobalt, mixed with the iron which it contained, is ground to powder, calcined again, and again ground, sifted and mixed with 2 parts of powdered flint or quartz;‡ it is then moistened and it becomes very hard, but it easily gives up its oxide to the nitric acid. Its color is gray.

(d.) *Smalt is a glass, colored blue by oxide of cobalt.*

The proportions vary with the richness of the ore; on an average, equal parts of the calcined and roasted ore, of ground flints and potash, are fritted together and then fused into glass;|| while still fluid, it is ladeled into cold water to crack it, and it is then ground in a mill made of two very hard stones, inclosed in a wooden case or in a cask; the grinding is laborious and difficult. Smalt, in flakes, is a very splendid blue glass.

(e.) *Powder blue is smalt, ground fine.* The smalt is obtained of different degrees of fineness, by agitating the powder in casks filled with water, and pierced with three openings, at different heights.¶

X. METALS.—*Cobalt forms alloys with most of the metals* and generally renders them granulated and brittle. It is extremely difficult to separate it, entirely, from iron and from nickel. It does not unite with bismuth or zinc, and scarcely with silver and mercury. It is easily alloyed, and in various proportions, with gold, platinum, copper, tin, iron, nickel and arsenic.

XI. POLARITY.—From analogy, *electro positive.*

XII. NATURAL HISTORY.

1. *The only important ore of cobalt is the arsenical.* By heat, it exhales arsenic, with the usual cloud and fumes, and oxide of cobalt remains. There are three varieties of this ore.

* Also in Bohemia, Silesia, Lorrain, Wirtemberg and Austria.

† The arsenic is detached "by criminals who are condemned to this work for crimes that by law deserve death." (Chaptal's Chem. 298.) In this manner, most of the white oxide of arsenic of commerce is obtained.

‡ Added as is said for concealment, the exportation of the purer oxide being prohibited.—*Aitkins' Dict.*

§ 1 part oxide, 1 potash, and 3 white sand, (Chaptal's Chem. 296;) as much potash as sand. (Thénard.)

|| At the bottom of the pots, bismuth is said to be always found, as it is often mixed with the ores of cobalt.

¶ The water of the first cock carries out the lightest blue, which is called azure of the first fire; the heavier particles fall more speedily; and the powder brought out at the three jets, forms what is called the azure of the first, second, and third fire.

(a.) *The bright white.*—It crystallizes in cubes and modifications of that figure; structure lamellar. Sp. gr. 6.3—6.5. Its composition is, cobalt 44. arsenic 55. and sulphur .50.

(b.) *The grey.*—Fracture even or granular; hard and brittle; never crystallizes. Sp. gr. 5.5. Composition, cobalt, 33.10, arsenic, 43.47, iron, 3.02, sulphur, 20.08.

(c.) *Tin white.*—Its crystals are very similar to those of (a.) fracture fine grained and uneven, with metallic lustre, brittle, hard; sp. gr. 7.3—7.7. Gives arsenical vapors with great facility, but melts only partially. Composition, cobalt, 20.31, arsenic, 74.21, iron, 3.42, copper, .15, sulphur, .88.

2. *There is a sulphuret of cobalt.*—Color, yellowish grey; composition, cobalt, 43.2, sulphur, 38.5, copper, 14.4, iron, 3.53; it is very rare.

3. *The oxide of cobalt is found as a black powder, mixed with other ores of this metal.*

4. *Salts of cobalt.*

(a.) *The arseniate.*—In a peach blossom efflorescence, or in prisms; by fusion, it tinges borax of a beautiful blue.

(b.) *The sulphate.*—Pale rose red, investing other minerals, or in red stalactites. These red appearances are very characteristic of cobalt, but may be mistaken for manganese; the blowpipe, with borax, will however distinguish them, as already described.

XIII. REDUCTION.

(a.) *The oxide* (obtained by roasting the arsenical ore,) 1 part, is mixed with 3 of black flux, 1 of dry sea salt, and $\frac{1}{2}$ a part of resin; heat is gradually applied in a crucible placed in a furnace, till the materials are white hot and the cobalt is reduced.

(b.) *Zaffre may be substituted*; process similar; the silex may be previously washed away, to diminish the labor.

(c.) *Detonate zaffre, three times successively, with one fourth of dry nitre and one eighth of charcoal powder; then add an equal weight of black flux and proceed, as above, till the metal is reduced.* To get rid of the iron, the pulverized metal is detonated with three times its weight of dried nitre; the iron becomes peroxide, and the arsenic becomes acid and unites with the potassa. The alkaline arseniate is washed away by water, and from the residuum cobalt is taken up by nitric acid, which leaves the iron; evaporate to dryness; redissolve in nitric acid; filter; decompose by potassa, and reduce the oxide by black flux.—(H.)

(d.) *Oxalate of cobalt, heated in a retort, from which the air is excluded, emits carbonic acid gas, and leaves metallic cobalt in the form of a black powder.** The oxalate is easily formed, by mingling ox-

* Ann. Philos. N. S. 1.

alate of ammonia and nitrate of cobalt; or it may be obtained pure, by dissolving zaffre in muriatic acid, and precipitating the arsenic, in the form of orpiment, by a current of sulphuretted hydrogen gas; the filtered liquor, being boiled with a little nitric acid to turn the iron into peroxide, is decomposed by carbonate of potassa, and the washed precipitate being digested with a solution of oxalic acid, a soluble oxalate of iron is removed, and the insoluble oxalate of cobalt remains.*

XIV. *Uses.*—*The most important have been mentioned.*

It is the only blue color which will endure in a furnace fire; the ultra marine is totally destroyed.

Its power is such, that 1 part of the oxide will give a full blue to 240 of glass, (Aikins,) and when melted by itself, the globule is so intensely blue, that it is opaque except on the thinnest edges.

Smalt is used by the sign painters; in the form of powder blue, by the laundresses, who mix it with starch; and in the preparation of cloths, laces, paper, linens, muslins, threads, &c. to impart a delicate blue, or to conceal some other tint.—*Chaptal.*

It has been already mentioned, that it is used in painting on porcelain, and the imitations of it.†

The finer kinds of porcelain are painted with the oxide of cobalt, prepared directly from the metal. The blue enamel is formed from smalt.‡

Remarks.

Gray cobalt is found, in considerable quantity, at Chatham,§ Conn. It is there, as is usual elsewhere, associated with nickel.

It is found also in the arsenical iron of Franconia, N. H. and the discovery of cobalt in that ore, after it had failed to affect ignited borax, should lead to a more careful examination of the arsenical pyrites which are so abundant in this country, as it is possible that they may, in various cases, contain this metal.

It would appear, that cobalt is generally present in meteoric iron, as Prof. Stromeyer has detected it in a specimen from the Cape of Good Hope,|| and in every aerolite that he has examined.

Cobalt is not used in medicine, and the metal is unknown in common life. Its name is said to be derived from *Cobalus*, the supposed demon of mines, who thwarted and destroyed the miners, and this metal appearing, at first, mysterious and untractable, was nick named cobalt.—*Ure.*

* Laugier.

† Some of it has a richness of color, far surpassing all other works of the pencil. This is particularly remarkable in the Saxon porcelain.—Bl. II. p. 601.

‡ It is not an oil color, which limits its use, and in painting, it cannot be substituted for ultra marine. § Six miles East of Middletown, near Connecticut river.

|| Thomson's Ann. XI. p. 348.

SEC. XXIV.—ANTIMONY.

I. NAME.—In Latin, *stibium*: the metal was anciently called *regulus** of *antimony* in distinction from the sulphuret, which was formerly, and is still named *crude antimony*.

II. HISTORY.—The ancients knew only the most common ore of antimony, without being able to extract the metal. The alchemists, in pursuit of gold and the alcahest and the catholicon, tortured this metal with acids, alkalies and fire, and thus made many of its properties known.†

III. NATURAL HISTORY AND EXTRACTION.

1. *Its ores.*

(a.) Among the rarities of cabinets, we find *white oxide* of antimony and the red sulphuretted, or, as formerly supposed, *hydro-sulphuretted oxide*, and the *antimonial ochre* and *yellow antimony*, whose composition is not exactly known; but none of these ores are of any practical importance.

(b.) *Native antimony*, almost exactly resembles the metal, extracted by art; it is also rare.

(c.) *The sulphuret is the only abundant ore.*—It occurs in prismatic crystals, from the size of needles and hair to that of a finger; the crystals are often aggregated in beautiful masses, sometimes with iris colors; it occurs more commonly compact. It resembles the sulphuret of lead, but is instantly distinguished by fusion, under the blowpipe, on charcoal; it melts easily, burns brilliantly with a white smoke of oxide of antimony and vapors of sulphur, and leaves no residuum. Its composition is about 3 parts antimony to 1 of sulphur.

2. *Extraction.*

(a.) *It is freed from stony matters, by simple fusion*, either on the floor of a reverberatory furnace, the ore being covered with ignited charcoal; or in a crucible or pot, perforated at bottom, and placed in the mouth of another, which is buried in the ground as high as its lip; a fire is now kindled around, and the melted ore runs through, congeals in the form of the recipient and, on being broken, presents a beautiful assemblage of needle crystals, much more closely connect-

* The term *regulus* was applied, by the old chemists, to a metal, as distinguished from its ores, and other combinations.

† The *Curvus triumphalis antimonii* of Basil Valentine, appeared at the close of the fifteenth century; and Lemery, three hundred years after, published the first scientific account of the subject; multitudes of chemists have examined it since, and augmented our knowledge. By medical men it has been alternately extolled as a panacea, and decried as a poison. Early in the seventeenth century, the French parliament, led by the faculty of Paris, first proscribed, and then restored both the antimonial medicines and those who employed them; the virtues of antimony are however, now too well known to be questioned, and it is regarded as one of the pillars of medicine.

ed, than in the natural specimens, and easily distinguished from them, by a practised eye. This is only a purified ore.

(b.) *To separate the sulphur*, most metals will answer; but iron, copper, lead, silver and tin, are the most effectual, and *iron is always preferred, both for energy and cheapness.*

Crude antimony, 4 parts, is *projected upon iron* nails, clippings or filings, *heated to whiteness*; the crucible is covered, and afterwards, about 1 part of *nitre being added, the metal*, aided by a slight jarring, *subsides*, and may be cast in moulds.*

Or, *the ore is carefully roasted*, without fusion, and with constant agitation; sulphur is dissipated and the antimony is oxidized; an equal weight of *black flux is then added*, and a strong *heat applied* in a crucible, *when the metal collects at the bottom.*

It is better, to mix the oxide with powdered charcoal and oil or fat, and when the metal begins to appear, nitre is thrown in, in the proportion of 1 oz. to 1 lb., and more and purer metal is obtained than in the other process.

Or, 8 parts of the powdered ore, † 6 of nitre and 3 of tartar, are mixed and thrown, by spoonfuls, into a red hot crucible, placed in a powerful furnace; the sulphur is burned and a black flux formed, which reduces the metal.‡

IV. THE METAL.

PROPERTIES.

(a.) *Antimony, obtained by the preceding process, is not quite pure*; it must be dissolved in nitro-muriatic acid, decomposed by water, and heated in a covered crucible, with 2 parts of crude tartar, (H.); or, digested a good while in strong muriatic acid, the sulphur, which is the contaminating substance, is removed in the form of sulphuretted hydrogen gas.

(b.) *Color, grayish or bluish white; brilliant*, somewhat like silver or tin.

(c.) *Texture lamellar*, breaking in intersecting plates.

(d.) *Structure, decidedly crystalline*, with an arrangement sometimes resembling fern leaves, stars or feathers.§

(e.) Primitive form, (Haüy,) an octahedron; integrant particle, a tetrahedron: by slow cooling after perfect fusion, *crystallizes in octahedra*; the crust being broken, the liquid interior is poured out.

* As it still contains both iron and sulphur, it is re-melted and about 1 part of crude antimony and another of nitre are added; to purify it still farther, this operation is repeated with nitre only; 18 parts of the sulphuret, with 8 of iron nails and 12 of nitre, after four fusions, gave 8 oz. of the metal.—Lemery and Beaumé, quoted in Aikins' Dictionary.

† Fourcroy, V. 300.

‡ The first process (by iron) is, according to my experience, the best; the last (with nitre and tartar) is quick, but inaccurate and not very productive.

§ The alchemists attached much importance to these appearances.

- (f.) *It imparts a peculiar smell and taste.*
 (g.) Sp. gr. 6.702, (6.424, Thomson;) scratches all the soft metals.
 (h.) *Very brittle*; pulverized by the hammer and pestle.
 (i.) *Melts at 810° Fahr. or just at ignition.*
 (j.) *In an open vessel, if the heat be raised, it evaporates, in the form of an oxide*, but it cannot be distilled in a retort, except when the oxide is mixed with charcoal and ignited, when the metal rises with the current of carbonic acid gas; if no gas passes over in the retort, only a few tears of antimony are collected in its neck.

V. RELATION TO OXYGEN.

1. Combustibility.

(a.) *Slightly tarnished by exposure to the air*; but dry air and even dry oxygen do not affect it.

(b.) *Heated to whiteness, with contact of air, it burns vividly*, with a bright white light and an abundant cloud of white oxide. The mouth blowpipe, well managed, will effect the combustion; but it is shown with the greatest beauty by the compound blowpipe, in the focus of which, the antimony, sustained on charcoal, burns with intense splendor, and, in both cases, the charcoal is stained white, and if the globule be thrown upon a table, or the floor, it divides into innumerable smaller globules, which rebounding and darting about in vivid combustion, mark their progress, by stains alternately black and white.*

(c.) *The same fact is shown, on a larger scale, by a crucible, covered, inclined, intensely heated, and then overturned.* The white cloud that rises and condenses on cold bodies, in acicular crystals, was formerly called argentine flowers† of antimony; and if the crucible be sustained in an inclined position, most of the oxide condenses around the metal.

2. *Action of water.*—At a common temperature, it is null; but steam, passing over ignited antimony, produces detonations; the metal is oxidized and hydrogen gas evolved.

3. OXIDES.—Proust admits two; Thénard, three;‡ Thomson three, and Berzelius describes four.§ Referring to the authorities cited below and to the larger systems of chemistry, for the grounds of the conclusion, we will adopt the opinion of Dr. Thomson, which is now generally received on this subject.

(a.) PROTOXIDE.¶—*Obtained, by decomposing the muriate of antimony by water*; clearing the precipitate|| of acid, by digestion, with

* Black from the carbonization of the wood by the hot metal, and white from the oxide constantly forming; the tracks look like those of little animals on clean snow.

† They were obtained also from the sulphuret.

‡ Formerly six.

§ Ann. de Chim. V. LXXXVI, p. 225, and LXXXIII and XXXII. Jour. de Phys. V. IV. Ann. de Chim. et de Phys. V. XVII. First Prin. Vol. II.

¶ The protoxide of Berzelius is obtained by galvanizing antimony at the positive pole, but is supposed to be a mixture of real protoxide and the metal.

|| Anciently called powder of Algaroth.

carbonate of potassa, and washing it with water; or, by dissolving antimony, in 4 parts of strong sulphuric acid, heating to dryness, and using alkali and water as above; or, by decomposing solution of tartar emetic by ammonia, washing in much hot water and drying.

It is obtained also, by heating antimony in a crucible, with excess of air, and receiving the sublimate in an inverted crucible, perforated and covered by another.—*Thénard*.

The protoxide is the basis of the antimonial salts; it is volatile, and can be sublimed in close vessels; it melts at ignition, becomes yellow and gray on cooling, and resembles asbestos: suddenly heated in contact with air, if porous, it inflames* and becomes deutoxide. The protoxide, obtained from antimonial salts, is grayish white, that from combustion, pure white. Its composition appears to be metal, 44,† one equivalent, and oxygen one, 8=52.

(b.) DEUTOXIDE.—Formed, by subjecting antimony to the action of strong nitric acid, and igniting the residuum: the metal is at first peroxidized, and the heat afterwards expels half an equivalent of oxygen: or, the precipitate, by water from the nitro-muriatic solution, is ignited in a platinum crucible; and with a regulated heat, it is perfectly snow white. It is distinguished from the peroxide by being infusible and fixed, and, after ignition, by insolubility in acids.‡ Its composition is one equivalent of metal, 44; + 1½ equivalent of oxygen, 12; =56.

(c.) PEROXIDE.—Formed, by deflagrating 1 part of antimony with 6 of nitre; heating for two hours; washing first with cold, and then with boiling water; digesting again, for several hours, with nitric acid; washing, drying, and heating gently in a platinum crucible, until a fine yellow color is produced.—*H*.

Or, antimony and strong nitric acid§ being mixed, and the product heated to dryness, and then, for some hours, to a temperature of 500° of Fahr. the hydrated peroxide loses its water and becomes a pure yellow peroxide. By a high heat, it gives up a part of its oxygen and becomes deutoxide.

The precipitate, by water, from the nitro-muriatic acid is peroxide. Its composition is, one equivalent of metal, 44; + two equivalents of oxygen, 16; =60.

Thus it would appear, that the oxygen in the antimonial oxides is in the proportions 8, 12, and 16, which forms another exception

* This happened to Berzelius in drying a precipitate by water from the nitric solution, and to Thénard while doing the same with a precipitate by iron from the muriatic; in both cases the matter burned like tinder.

† By the analysis of Berzelius 43 is the equivalent of antimony, but the British chemists adopt 44.

‡ Its hydrate is soluble.

§ Ann. of Philos. N. S. II. p. 125.

from the laws of definite proportions, unless we suppose that the lowest oxide has not been, as yet, discovered.*

VI. ACTION OF CHLORINE.—CHLORIDES.

1. PROTOCHLORIDE.

(a.) *Warm chlorine gas promptly burns antimony,*† producing a chloride, in white fumes.

(b.) *The proto-chloride is usually formed, by distilling powdered antimony, 1 part, with corrosive sublimate $2\frac{1}{2}$: it may be redistilled with a gentle heat, and is a soft deliquescent corrosive solid, formerly called butter of antimony ; it easily melts, and on cooling, crystallizes in prisms ; water decomposes it, throwing down protoxide, and if abundantly added, sub-muriate of the protoxide ; the muriatic acid can be removed, by washing with an alkali.*

It is composed of antimony, one equivalent, 44 ; + one equivalent of chlorine, 36 ; =80.

2. PER-CHLORIDE.—*Formed, by passing dry chlorine gas over heated antimony : there is a combustion ; and a transparent, volatile fluid distils over, which, with a little water, forms a crystalline mass,‡ and with more, precipitates the peroxide of the metal.§ Its composition is 2 equivalents of chlorine, 72 ; +1 of antimony, 44 ; =116.*

Dr. Thomson describes another chloride, or dichloride, containing 2 equivalents of metal, 88 ; +1 of chlorine, 36 ; =124.||

VII. IODINE, *in excess, heated in a glass tube with powder of antimony readily combines with it, and forms an iodide, whose color is dark red, and which is, by water, converted into oxide of antimony and hydriodic acid.*

VIII. COMBUSTIBLES.

1. PHOSPHORUS.—*The phosphuret is unimportant ; it is formed in the usual way ; ¶ it is white and brilliant, fragile, lamellar, very fusible, decomposable by a high heat, and with the blow pipe gives a small green flame and white vapors.*

2. SULPHUR, as already stated, exists in natural combination with antimony.

(a.) *The metal and sulphur can be united by fusion, in the proportion of one equivalent of antimony, 44 ; and one of sulphur,*

* The deutoxide of antimony has been called the antimonious, and the peroxide the antimonic acid, because they do not enter into combination with acids, but with alkalies to form salts ; the antimonious acid, when separated by an acid from these combinations, is a hydrate, and is then soluble in muriatic acid.

† The sulphuret is even more inflammable ; it may be thrown in powder, into a tall glass tube, stopped at one end, and filled with chlorine gas.

‡ Resembling the fuming liquor of Libavius, the chloride of tin.

§ Ann. of Philos. N. S. Vol. X.

¶ First Princ.

¶ See the phosphurets, p. 122.

16; =60, and the compound is in all respects similar to the native mineral.*—*Thomson.*

(b.) *If sulphuretted hydrogen gas be passed through a solution of tartar emetic, a sulphuret is in that way produced; it is orange yellow, and has been regarded as a hydro-sulphuret of the oxide: but Dr. Turner says that after the precipitate is well washed, sulphuric acid does not disengage from it any sulphuretted hydrogen.*

(c.) *The native sulphuret, or rather that which has been once melted down from the ore, is always used for chemical experiments. It melts without losing its sulphur, and on cooling, crystallizes with the metallic brilliancy.*

IX. ALKALIES.—KERMES MINERAL.—SULPHUR AURATUM.—Intimately connected with the sulphurets of antimony, is the action of alkalies upon the native sulphuret, for they exert little or no action upon the metal.

1. *The kermes mineral.*†—Numerous recipes have been given for the preparation of this compound.

(a.) 1 part sulphuret of antimony is melted with two of sulphur of commerce, and boiled for half an hour with 22 parts sub-carbonate of soda and 250 of water; the kermes is deposited as the solution cools.

(b.) Sulphurets of antimony, 1, + potassa, 2, and sulphur, 1; melt them in a crucible; pulverize; boil in water; filter, and the brown kermes falls.‡

(c.) Solution of potassa 4 pounds, water 3, prepared sulphuret of antimony 2, boil for three hours with agitation, and add water as it evaporates: it is to be strained, and most of the antimony will remain suspended until an acid is added. This last is the process of the pharmacopœia.

It is essential to the beauty of the kermes, that the solution should cool very slowly while it is depositing.

(d.) It is quite sufficient for obtaining the kermes, to boil for a quarter of an hour caustic fixed alkali, 1 part, dissolved in from 20 to 25 of water, upon 2 of pulverized sulphuret of antimony.

2. *Sulphur auratum, or golden sulphur of antimony.*

(a.) As in all the preceding processes, the greater part of the antimony remains in solution after the fluid is cold; a diluted acid, (the sulphuric or muriatic) is then added, which engages the alkali, and precipitates abundantly, a yellow substance, extremely similar to

* Thénard, 2d Ed. Vol. I p. 572, directs that equal quantities of antimony and sulphur should be used in forming the artificial sulphuret.

† Discovered by Glauber, and revealed by a pupil of his to the surgeon La Legerie, and by him to a monk of the name of Simon, who enriched his order, by the sale of the medicine; it was called *poudre de chartreux*, and was regarded as a specific in complaints of the breast. In 1720, the French government bought the secret and made it public.—*Laugier and Thénard.*

‡ It is inferior to that obtained in the humid way, and is used in veterinary practice.

the kermes mineral, and which is called sulphur auratum, or golden sulphur.

(b.) Chemists have not been exactly agreed as to the nature of the *kermes* and the *sulphur auratum*.

(c.) The more probable opinion seems to be, that both are *hydro-sulphurets of the oxide of antimony*. Dr. Thomson thinks, that the kermes is composed of protoxide of antimony, 52; and sulphuretted hydrogen, 17; each one equivalent; =69; and it has been supposed, that the sulphur auratum is a sulphuretted hydro-sulphuret. Others contend, that both are essentially hydrated sulphurets, because, by careful washing with boiling water, the sulphuretted hydrogen can be withdrawn, so that none of it will be disengaged by the addition of sulphuric acid, and they are found to be in the same condition as the precipitate made by passing sulphuretted hydrogen gas through solution of tartar emetic, or of other antimonial salts;* or by decomposing such solutions by hydro-sulphuret of an alkali.

(d.) The golden sulphuret of antimony is called by some a per-sulphuret; and a deuto, or sesqui-sulphuret has been formed, by passing sulphuretted hydrogen gas through a solution of the deutoxide in muriatic acid.†

(e.) Mr. Rose has proved that the *red antimony* of the mineralogist is composed of 1 equivalent of the protoxide, with 2 of the proto-sulphuret of antimony, and that the *glass, liver, and crocus* of antimony have a similar composition.

(f.) *The glass of antimony is made by roasting the pulverized sulphuret in a shallow earthen vessel*: the sulphur is in part expelled, while the antimony is oxidized, and by an increased heat the mass is melted, the silica,‡ (of which, it contains about 10 per cent,) contributes to this vitrification, and it becomes translucent, with a beautiful hyacinthine red color.

(g.) *The crocus, and the liver of antimony, are formed in a similar manner*, only with a different management of the heat, and with a greater or less proportion of the ore: they are opaque, and of the color of liver. The crocus, and the liver of antimony, are often employed in veterinary medicine. According to Thomson, the glass is

* There is little reason to doubt that both precipitates are hydro-sulphurets, and as the addition of the acid to decompose the antimonial solution disengages sulphur as well as sulphuretted hydrogen, there seems good ground for the opinion of Thénard, that the sulphur auratum contains the most sulphur. The removal of the sulphuretted hydrogen by water, is an occurrence similar to that of the decomposition of the acid solutions of bismuth and antimony in water. Nor is the fact, (Gay Lussac's Cours. II, Leçon. 20, p. 21.) that heat evolves from these compounds only water, any decisive proof that they do not contain sulphuretted hydrogen, for the hydrogen of the latter, with the oxygen of the oxide of antimony, would form water, while the sulphur would combine with the metal and form the sulphuret that is left.

† For the method of forming it, see Henry, 11th Ed. II. p. 88, and Ann. of Philos. N. S. Vol. X.

‡ Derived from the vessel

composed of sulphuret of antimony, 1 part, and oxide, 8; the crocus of 1 and 4, and the liver of 1 and 2.

X. *Acids.*—*Most acids act on antimony*; some more readily on the protoxide, few unite with the peroxide.

1. *Strong sulphuric acid.* *In the cold, no action, but with heat, the acid imparts oxygen*, while sulphurous acid gas is evolved, and with a high heat, a little sulphur is sublimed. *With moderate heat, the compound is a sub-sulphate*, a soft, white, humid mass, decomposed by water, most of the oxide being precipitated.

2. *Nitric acid acts with energy*;* nitrous oxide gas is disengaged, and the deutoxide is formed,† but not dissolved, and any small portion that is taken up is precipitated by water. *Ammonia is formed during this action*, and may be disengaged by lime or caustic fixed alkalies which unite with the acid. Water affords the hydrogen, and the acid the nitrogen, the two elements of the ammonia. Crystals of nitrate of ammonia are sometimes formed.

The sulphuret of antimony is affected by nitric acid in a similar manner.

3. *Muriatic acid.*

(a.) *Action slight, even with heat*; of the small portion that is dissolved, the greater part is deposited on cooling, but by evaporation, minute deliquescent acicular crystals are obtained.

(b.) *The strong muriatic acid, with heat, acts easily upon the sulphuret of antimony*; water is decomposed, sulphuretted hydrogen gas disengaged, and muriate of antimony formed.

4. *Nitro-muriatic acid acts vigorously*, even with only one tenth of nitric acid, but with one fifth or one fourth the solution is rapid, and attended by the usual phenomena; *and muriate of antimony is the result.* *It was formerly called*, from its consistence, *butter of antimony*, and is a *white, deliquescent, fusible, and very acrid mass*; it can be distilled and crystallized; it is decomposed by water, which gives a sub-muriate.‡

The muriate of antimony may be produced from corrosive sublimate and antimony, as already mentioned, (see the chloride,) *or from unwashed sulphate of antimony and common salt*, distilled to dryness. The solution of chlorine also dissolves it.

5. *Other acids act feebly on antimony*, but a number dissolve its oxides; especially the tartaric acid, producing tartar emetic, which

* If the antimony is in fine powder, the acid strong and fuming, and in such quantity as to form a thick semi-fluid mass, it even produces inflammation. Aikins' Dict.

† Antimony may be in this manner, separated from lead and other soluble metals.

‡ Formerly called *mercurius vitæ*, or powder of Algaroth, from Algarotti, an Italian, its discoverer: a peroxide of antimony produced by the action of nitric acid upon the muriate of antimony, was anciently called *Bezoar mineral*.

is usually formed by the aid of cream of tartar, (bi-tartrate of potassa.)

6. TARTAR EMETIC.—*This important medicine is a triple compound of tartaric acid, protoxide of antimony, and potassa.**

PROCESSES.

(a.) *Pulverized glass of antimony, 12 oz. and boiling hot solution of 16 oz. of cream of tartar, in 14 quarts of pure water: digest for half an hour, and boil for ten minutes; evaporate nearly to dryness, to separate silica; redissolve in hot water; strain, evaporate to a pellicle, and allow it to stand to crystallize.—A.*

The crocus† and the submuriate have been substituted for the glass of antimony: all that is wanted, is to supply oxide of antimony to the cream of tartar.

(b.) *Pulverized protoxide of antimony, 2 parts, boiled with 1 of solution of cream of tartar.—G. L.*

(c.) *Sub-sulphate of antimony, made by boiling‡ to dryness, 200 parts of sulphuric acid upon 100 of powdered antimony, and 100 parts of the residuum boiled with 100 cream of tartar, after due evaporation, gives, at the first crystallization, 90 of tartar emetic in crystals.§*

(d.) *The composition of tartar emetic is, according to Dr. Thomson,*

Tartaric acid,	2 equiv.	$66 \times 2 = 132$
Protoxide of antimony	3 “	$52 \times 3 = 156$
Potassa,	1 “	48
Water,	2 “	18

354

Mr. R. Phillips gives three equivalents of water, making in the whole, 363.

PROPERTIES.

(a.) *A valuable emetic, cathartic, diaphoretic, rubefacient, &c. according to the doses and mode of administration.* In large doses, it is a poison.*

(b.) *Its purity can be relied on, only when it is crystallized, when from whatever source derived, its composition is the same; form, the tetrahedron, or octahedron; it reddens litmus; taste, nauseous and caustic; slowly effervescent.*

* Some have preferred to regard it as a compound of two salts, the tartrate of potassa, and the tartrate of antimony, or of oxide of antimony, united to the vegetable salt, acting entire, in the character of an acid.

† Made by deflagrating equal parts of sulphuret of antimony and nitre.

‡ In an iron vessel.

§ R. Phillips, in the London Pharmacopœia. The process (a.) is the old one, and I have always found it successful.

* Dose for an emetic, 2 to 3 grains; for a diaphoretic, $\frac{1}{2}$ to $\frac{1}{4}$ of a grain, and as an expectorant, in still smaller doses: as a rubefacient, 1 drachm, or 2, to 1 oz. of lard, or better, of French pomatum; it is applied in plaster, or simply rubbed on the part.

(c.) *Soluble in 2 or 3 parts of water, at 212°; in 15 at 60°.*

(d.) *Decomposed by acids and alkalies, and their carbonates, and by the alkaline earths; the former precipitating the cream of tartar, and the latter the oxide of antimony.*

(e.) *Sulphuretted hydrogen, and hydro-sulphurets precipitate kermes mineral,* from its solution, and thus counteract its poisonous character in the stomach, which is effected also, to a degree, by demulcent drinks, and infusions of bark and gall-nuts.*

(f.) *Its solution is spontaneously decomposed; it is blackened by heat, and if ignited with black flux, it yields up the metal.†*

IX. POLARITY.—*Electro-positive.*

SEC. XXV.—ZINC.

1. HISTORY.—*First mentioned by Albertus Magnus, who died in 1280. The East Indians and Chinese knew it before the Europeans: the Greeks and Romans used some of the alloys of zinc and copper, which they formed by an ore of zinc, then called cadmia, and now calamine. The word zinc occurs first in the writings of Paracelsus, who died in 1541.‡ The artists sometimes call it spelter.*

II. PROPERTIES.

(a.) *Color, brilliant bluish white; texture, laminated; breaks in plates a little ragged; imparts a peculiar taste and smell, when rubbed by a warm or moist hand.*

(b.) *Sp. gr. 6.8 to 7, and after compression 7.19; rather tough than brittle; in thin plates, ($\frac{1}{8}$ inch,) breaks easily, but if thick (1 inch,) it bears a heavy blow of the hammer,§ and is indented by it.*

(c.) *Laminable in the cold, by careful and equal pressure between the rolling cylinders; between 210° and 300°|| Fahr. highly lamina-*

* This is readily distinguished from the yellow precipitate given by sulphuretted hydrogen with arsenic, as the latter will give the alliacious odor on burning charcoal.

† It is easily carbonized, and decomposed by the mouth blow-pipe, and carbonate of potassa, and metallic antimony are left on the charcoal; I have detected it in this manner, when it has been introduced in large quantity into drinks, so that a great number of persons at an entertainment, were made violently sick.

‡ More particular information concerning the history of this metal may be found in Bergman's works, Vol. II, p. 314, and in Dr. Watson's Chemical Essays, Vol. IV. The mode of extracting this metal from its ores, has not been known much over a century in Europe, and seems first to have been discovered by Dr. Isaac Lawson, Id. p. 36, although Von Swabb instructed the Swedes in it about the same time. In the course of the 16th century, zinc was brought to Europe from the East.

§ If the two ends of the common cakes of zinc are supported, and the blow applied in the middle, they break without much difficulty.

|| Discovered and patented by Messrs. Hopson and Sylvester, (Phil. Mag. Vol. XXIII.) The plates are of great use in covering houses, and in lining baths and aqueducts, and it has been proposed to sheath ships with them.

The following is from Prof. Griscom.—I have been informed by a merchant of New York, that he covered the bottom of a vessel with zinc plates, fastened with zinc nails; but she returned so exceedingly foul, that they were obliged to remove the zinc and substitute copper. Large oysters were found adhering to the zinc.

ble and ductile, and the plates, after being annealed, are elastic when cold, but if folded with a sharp edge, they crack.

(d.) *Less ductile than laminable*; the wire, in large curves, is sufficiently flexible, but snaps by a short turn, and both it and the plates, exhibit, at the fracture, the usual crystalline structure of zinc.

(e.) *Tenacity of the wire* such that when $\frac{1}{8}$ of an inch in diameter, it sustains 26 lbs. (Muschenbroeck,) but it can be drawn to $\frac{1}{16}$ of an inch in diameter, and is then *nearly as tenacious as silver*.

Moderately hard; clogs a file, and soon renders it quite smooth.

(f.) *Melts below ignition*, at 680 to 700° Fah.; *very volatile*; and in a stone retort, may be distilled over, and condensed under water, contained in a receiver, and thus purified from iron,* carbon, &c.

(g.) *By very slow cooling after fusion*, it may be made to crystallize in prisms;† very expansible by heat.

(h.) *Heated to about 400°*, it may be pulverized in a hot mortar with a hot pestle; it may be divided also by pouring it, when melted, into water.

(i.) If a cake of zinc be laid upon burning coals, and when it is on the point of melting, which is indicated by its beginning to burn with a blue and white flame, it be then quickly withdrawn and laid on a flat stone, it may be easily knocked to pieces by quick blows of a hammer; some of it will be in powder, and some in coarse and fine fragments, fitted for experiments.

III. ACTION OF OXYGEN.

1. Combustibility.

(a.) *Zinc is eminently combustible*; above ignition, it burns with a very bright and dazzling white and blue flame.

(b.) *Heated nearly to a white heat*, in a covered crucible placed at an angle of about 45° in a furnace or forge fire, the cover being suddenly removed, *the zinc burns with intense splendor*.

(c.) The metal may be stirred with an iron rod to renew the contact with the air, and if held aloft and poured slowly upon a stone or brick floor, it descends in a burning sheet, and is dashed about in a fiery spray.§

(d.) *Zinc shavings and very thin leaves*, will burn in a candle and upon a red hot iron or coals, and masses of it are exhaled and burned in a common fire.

* According to Dr. Thomson, (First Prin. I, 52,) the zinc of commerce is never quite pure, and frequently contains carbon.

† The best method is to pour off the fluid metal from below, after the surface has congealed.

‡ It exposes a larger surface of the oxide, and is more easily collected.

§ In the combustion of this metal, the compound blowpipe is superfluous, and indeed, in the focus of that instrument, the metal is oxidized so rapidly that the combustion is impeded, and is renewed only occasionally, in jets, as the vapor darts through.

2. OXIDE.

(a.) *The combustion produces a light flocculent white or yellowish oxide*, formerly called *lana philosophica*, *pompholix*, *nihil album*,* &c. Much of it rises mechanically in the current of hot air, and floats about the room.

(b.) *It is fixed in the fire and melts into a fine yellow glass.*

(c.) *Zinc tarnishes but slightly in the air*; but when heated, its surface becomes gray, and by agitation below its evaporating point, it is converted entirely into a grayish substance, which is probably a mixture of the oxide and metallic zinc.

(d.) *Composition*, according to Dr. Thomson, 1 equivalent of zinc, 34, + one of oxygen, 8=42, its equivalent; there is only one oxide.

One half of the oxygen can be expelled by heat, which appears to indicate a sub-oxide, but the white oxide is the only one certainly recognized.†

(e.) *Oxide of zinc is insoluble in water*; it is a powerful base with acids; in the shops, it is called flowers of zinc, and is sold as an antispasmodic.

IV. *WATER is slowly decomposed by zinc*, in the cold; rapidly at ignition; hydrogen gas being evolved in torrents, requiring some caution.

V. *Iodine combines with zinc*, and forms a compound, which is fusible and crystalline. Dr. Thomson states its composition as being

iodine, 1 equivalent,	-	-	124	} per cent. {	78.48
zinc, 1 . “	-	-	34		21.52
			158		100.00

Iodide of zinc deliquesces into hydriodate of zinc, and a solution of this, with one of corrosive sublimate, produces a beautiful bright scarlet color.—H.

VI. *Chlorine gas, warm and dry, inflames zinc filings*, and produces a chloride, of a whitish gray and semi-transparent. (See the muriate.)

VII. COMBUSTIBLES.

1. *Hydrogen gas, evolved from water and sulphuric acid by the action of zinc, burns with a brighter flame than common hydrogen*, and probably carries over a little zinc, although it may be only in a state of mechanical suspension.

* If the inclined crucible in which the zinc is burning be allowed to remain undisturbed, a great deal of the yellowish white oxide will condense about its mouth.

† Laugier, (Cours de Chimie, II, 43.) says, that a deutoxide is formed, by adding oxygenized water, acidulated by nitric acid, to a weak solution of nitrate of zinc and adding a dilute solution of potassa; he states that the deutoxide spontaneously loses its oxygen without the aid of heat.

2. *Blende, composed of sulphur, and zinc*, is a very frequent mineral. *It is rather difficult to combine zinc and sulphur by art, but it may be effected;*

(a.) By igniting zinc or its oxide with flowers of sulphur in a crucible lined and covered with charcoal;

(b.) By igniting together sulphate of zinc and charcoal;

(c.) By drying the precipitate made in a salt of zinc, by hydro-sulphuret of ammonia;

(d.) By passing vapor of sulphur over melted zinc contained in an earthen tube.

The compound possesses no particular interest.

Both the natural and artificial sulphuret appear to contain 1 equivalent of sulphur, 16, with one of zinc; but the zinc seems to be rather less than in the oxide; instead of 34, it is from 31.50 to 33* in different analyses, but we may presume that there was some error.

3. *Phosphorus combines with zinc*, in the manner described, page 122 of this volume.

Phosphuret of zinc resembles lead in its appearance; it has the metallic splendor and a white color, with some degree of malleability, and when hammered, emits the odor of phosphorus and burns when exposed to a strong heat.

Carbon can hardly be said to form a distinct compound with zinc, although it more or less contaminates the zinc of commerce.

VIII. ACIDS.

Zinc combines with most of the acids; the attraction is so strong, that they are more completely neutralized by it than by most of the metals, and are not, as in the case of antimony and bismuth, easily separated by large dilution with water.

1. *Strong sulphuric acid*, with the aid of heat, *oxidizes the metal* emits sulphurous acid gas, and forms sulphate of zinc.

The diluted acid acts promptly and vigorously on zinc; the water affords hydrogen gas, while its oxygen unites with the metal; the acid is unaltered, and may all be transferred to an alkali, and no sulphurous acid gas is disengaged.

This is one of the most eligible modes of obtaining hydrogen gas.

The sulphate of zinc—white vitriol of the shops—crystallizes in quadrilateral prisms; taste, styptic; soluble at 60° in 2½ parts of water; effloresces; decomposed by the alkalies and their carbonates.†

The oxide is soluble in alkalies, especially in ammonia, and this affords a mode of separating it from other metals; the precipitate by

* Thomson. Arfwedson. Berthier.

† The precipitate, especially if made with the carbonate of an alkali, is sometimes employed in painting.

the carbonates of the fixed alkalies, is not redissolved by an excess of the precipitant; but the carbonate of ammonia dissolves the precipitate. The sulphate of zinc of commerce, usually contains oxide of iron,* which gives it a yellowish hue.†

COMPOSITION, in crystals, acid,	1 equiv.	=40
oxide,	1 "	=42
water,	7 "	=63

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If deposited from a hot solution, it has only three equivalents of water; this is the condition of the common white vitriol of the shops,

1. *The sulphurous acid, dissolves zinc*, but the sulphite is unimportant.

2. *Strong nitric acid acts on zinc with great violence*,§ it is rapidly oxidated, and clouds of nitrous acid vapor are emitted.

(a.) *The decomposition of the acid evolves occasionally, all the subordinate compounds of nitrogen and oxygen*,|| and sometimes even pure nitrogen gas.

(b.) *The acid is diluted in order to form a nitrate of zinc.*

3. *Muriatic acid*, with or without dilution, *rapidly dissolves zinc*, and evolves torrents of very pure hydrogen gas, arising from the decomposition of water.

(a.) *Solution colorless*, does not crystallize by evaporation, affords a fusible white mass,¶ deliquescent, and volatilizable in delicate white needles. *By additional heat in a close vessel, it loses water or its elements, and becomes a chloride*, which does not rise at ignition; heated in the air, it loses muriatic acid and leaves oxide of zinc.**

(b.) *Crystallizes in prisms of four sides; caustic; deliquescent*; soluble in both water and alcohol; decomposable by heat, by the sulphuric acid, and by alkalies, affording with the latter, a very white oxide of zinc.

(c.) *The muriate of zinc, in strong solution, is partially decomposed by water*, it is decomposed also by the sulphuric acid, and by the alkalies; the solution is acid, although consisting of equivalents

* This however will not be the case, if in preparing the sulphate, we put into the sulphuric acid more zinc than it is able to dissolve.

† It is prepared at Goelar, in Saxony, by roasting *blende*; the sulphur becomes acid, and the metal oxide, and thus the salt is formed, and obtained by solution and crystallization. The foreign metals especially copper, lead, and iron are precipitated by oxides of zinc, or metallic zinc, added to the solution. It is usually granular, and often spotted with yellow.

§ Even inflaming it, (as is said,) if in fine powder.

|| When 1 part of nitric acid, 4 parts of water, and zinc in pieces (not in shavings,) are mixed, the product is almost totally nitrous oxide, but not pure enough for breathing.

¶ Formerly called butter of zinc. Dr. Black (Vol. II, p. 587,) suggests that it may be employed as a bird-lime.

** Brande.

of each of its constituents, and ammonia does not render it neutral till the whole of the oxide of zinc is precipitated.

4. *Phosphoric acid dissolves a portion of zinc, and evolves hydrogen gas.* No crystals are obtained by evaporation, but a gelatinous mass. Phosphate of soda and sulphate of zinc produce the same salt by double exchange.

5. *Carbonic acid, in watery solution, dissolves a little zinc.*

The carbonate of zinc may be readily formed by precipitation by alkaline carbonates, from the acid solutions.

6. *Even the vegetable acids dissolve zinc without difficulty, and with a disengagement of hydrogen gas.*

*The acetate of zinc is formed directly or by double exchange between the acetate of lead and the sulphate of zinc;** it is used as a collyrium, and as an astringent injection. The oxides of zinc are soluble in the acids without effervescence.

IX. BASES.

(a.) *Alkaline solutions, at ebullition, dissolve some zinc*—hydrogen gas is disengaged, and acids precipitate a white oxide.

(b.) *Ammonia is more efficient in this way than potassa or soda.* The oxide is precipitated from all these solutions, by the carbonic acid and oxygen of the air. Ammonia affords the best means of getting zinc pure.†

With ammonia and the sulphate of zinc, there is a mixed precipitate of the oxides of zinc and iron—an excess of ammonia will dissolve only the former, and the ammonia being neutralized by an acid, the oxide of zinc will be obtained pure.‡

(c.) The oxide of zinc is used with arsenic to give the opaque white color to glass.

X. SALTS.

(a.) *Aided by heat, zinc causes the sulphates to become sulphurets,* which dissolve a small portion of the oxide. Alum is decomposed by zinc, by means of boiling.

(b.) *The nitrates, at a red heat, deflagrate with zinc,* with bright light and much heat; 2 or 3 parts of nitre mixed with 1 part of fine zinc filings, are thrown into a red hot crucible. This mixture is used in fire works to afford a white light with a tinge of blue. In experiments with these materials, much caution is requisite, as a sudden

* Proportions, white vitriol, one drachm; sugar of lead, 4 scruples; distilled water, 20 oz.; dissolve each salt separately in half the water, mix and precipitate. It is said to be better to decompose the dilute solution of acetate of lead by suspending in it metallic zinc, for in this way no sulphate of lead is held in solution. If there is no lead, sulphuretted hydrogen causes a white precipitate.

† Hope, Note Book.

‡ The ammonia is added slowly; otherwise the solution is so prompt that we scarcely perceive the precipitation.

and violent detonation sometimes happens, throwing the burning zinc and hot nitre all around.

The zinc and nitre may be melted together in a crucible, and the action will be brought on promptly, by throwing in ignited charcoal. A cartridge may be charged with the mixture of nitre and zinc, and inflamed by a burning coal; it should stand under a chimney.

(c.) *Chlorate of potassa, 2 or 3 parts, with zinc in fine powder, 1 part, when struck on an anvil, detonates violently, and burns brilliantly by contact of a red hot coal.*

(d.) *Muriates.*—When zinc is rubbed with muriate of ammonia, the alkali is liberated, and obtained by distillation. Most of the metallic salts are decomposed, and most of the metals are precipitated by means of zinc, and hence it is very useful in the analysis of ores.

XI. ALLOYS.

With most of the preceding metals, zinc does not form any interesting combinations, but it is otherwise with several that are to follow. With antimony, however, it unites by fusion, and forms "a compact gray homogeneous brittle mass; density less than that of the constituents."

XII. *NATURAL HISTORY.*—*Its two principal ores are denominated calamine and blende; the former is not rare, and the latter is abundant.*

The calamine, the only profitable ore of zinc, usually resembles an earthy substance more than a metal; it is of various colors, and is often porous, although sometimes crystallized in rhomboidal tetrahedral prisms, or in hexahedral pyramids. It is an oxide, or a carbonated oxide, often combined with silica.

Blende, which is a sulphuret, is usually crystallized, and in very various forms; most commonly it is in tetrahedra, octahedra, or dodecahedra. Its prevailing colors are brown, violet, black and red, and sometimes it is yellow; sometimes semi-transparent, and beautiful as a gem; sometimes phosphorescent in the dark, even when a knife is drawn over it.

XIII. EXTRACTION.

(a.) *A rude assay is made, by mixing the calamine or the roasted blende with charcoal, and igniting them in a crucible over which a plate of copper is laid; if zinc is present, it will convert the lower part of the plate into brass.*

(b.) *The zinc of commerce was formerly brought exclusively from China; now it is abundantly manufactured in Europe, and as it is a volatile metal, it is always obtained by distillation.* For this purpose, the ore, almost always calamine, is sorted, roasted and mixed with about $\frac{1}{4}$ or $\frac{1}{5}$ charcoal powder, and heated in a furnace, in earthen crucibles, covered at top and having an iron tube perforating the bottom, or in earthen tubes stopped at one end and placed horizontally or vertically, and in the latter case the upper end is stopped.

Sometimes two tubes are joined at a rising angle, and the ends are depressed; one of them contains the materials, and the other receives the vapor. In all these cases the distilled zinc passes into water where it is condensed.*

XIV. Uses.

(a.) *Important*.—In medicine, its sulphate, 10 grs. or more, is a quick emetic; in smaller doses, used as a stimulant, &c.; its acetate is a collyrium, astringent, &c.

Its oxide is an anti-spasmodic and exsiccant.

(b.) In the arts, sheet zinc is much employed as a substitute for sheet lead, in covering houses, lining baths, water conduits, &c.; brass is formed from zinc and copper.

(c.) In chemistry, to afford hydrogen gas; for galvanic apparatus; as a constituent of amalgams for exciting electrical machines.

SEC. XXVI.—CADMIUM.

I. HISTORY.—*Discovered in 1817, by Prof. Stromeyer, of Göttingen*, in an oxide of zinc,† from a Silesian ore, and afterwards in various other ores, especially a radiated blende from Bohemia, which contained 5 per cent. Dr. Clarke found it in the Derbyshire and Mendip ores, and Mr. Herapath, in the sublimate, which, from being more volatile,‡ first rises in distilling zinc at Bristol, and which the

* At Rammelsburg, in Saxony, the following process is used. In the side of the furnace, (which is a reverberatory,) opposite to the bellows, the wall is double, consisting of two thin fire stones, with a hollow between. On a level with the usual surface of the melted metal, there is a chink, opening into this cavity. The zinc evaporates as fast as it is formed; and the vapor is driven into this hollow through the chink by the blast of the bellows. The side of the cavity, which is in contact with the air of the hut, is cool in comparison with the rest, the stone being thin and being often sprinkled with water. Here therefore the sublimed metal attaches itself, while the flowers, which are unavoidably formed by the calcination of part of this metallic vapor, rise farther up and get into the long funnel, where they collect and are got out from time to time by the name of *cadmia fornacum*—*tutia*, (or *diaphryges*.) Black, II, 591.

Dr. Watson, (Essays, IV, 38,) thus describes the process as practiced in England. "In a circular kind of oven like a glass house furnace, there were placed six pots about four feet each in height, much resembling large oil jars in shape; into the bottom of each pot was inserted an iron tube, which passed through the floor of the furnace into a vessel of water. The pots were filled with a mixture of calamine and charcoal, and the mouth of each was then close stopped with clay. The fire being properly applied, the metallic vapor of the calamine issued through the iron tube, there being no other place through which it could escape, and the air being excluded, it did not take fire, but was condensed into small particles in the water, and being remelted, was formed into ingots." The ores of zinc are wrought extensively for the formation of brass by union with copper, under which metal it will be mentioned again. For details, see Gray's Operative Chemist, p. 733; Thénard, 5th Ed. Vol. III, p. 508, and Aikin's Dict. Vol. II, p. 560.

† Prepared for medical purposes.

‡ According to M. Gay-Lussac, (Ann. de Chim. et de Phys. Vol. XXI, p. 218,) this sublimate rises first because the oxide or sulphuret of cadmium is more easily reduced than that of zinc.

workmen call the brown blaze ; its proportion is from 12 to 20 per cent.*

In calamine, it probably exists as an oxide ; in blende, as a sulphuret.

II. PREPARATION.

(a.) *Assay*.—To decide whether an ore of zinc contains cadmium, a fragment of the ore supported on platinum foil, is heated with the blue flame of the blowpipe ; if present, its oxide will be evolved, and will stain the platinum with a peculiar reddish brown color ;

Or, the neutral muriate of the zinc ore, after dilution, yields to iron all the metals which it will precipitate, and then a piece of zinc in a platinum capsule will throw down all the cadmium from the solution ; the precipitate, which is of a dull leaden color, adheres so tenaciously to the dish, that it may be washed without danger of being lost ; it is then dissolved in muriatic acid, the muriate is decomposed by an alkali, and the oxide treated as above by the blowpipe.

(b.) *Process of Stromeyer*.—From the solution of the sulphate or muriate of the zinc ore, having an excess of acid, a stream of sulphuretted hydrogen precipitates the sulphuret of cadmium, while the zinc remains in solution. The washed precipitate being dissolved in muriatic or nitric acid, the excess of acid is expelled by evaporation, the dry salt being again dissolved in water and decomposed by carbonate of ammonia in excess.† The ignited carbonate yields a pure oxide, and the oxide, being heated red hot in a glass tube in mixture with charcoal and oil, metallic cadmium is sublimed into the neck of the retort, whence it may be detached, and it is afterwards melted in a crucible.

(c.) *Process of Herapath*.—The sublimate, in the zinc manufactures, contains oxide of cadmium mixed with soot, sulphuret of cadmium and oxide of zinc ; this sublimate is dissolved in muriatic acid and precipitated by zinc ; it falls in thin flakes which are made to unite by being melted in a glass tube with a little wax and lamp-black.‡

III. PROPERTIES.

(a.) *Color*, white and brilliant like tin, but with a slight shade of bluish gray ; it is harder and more tenacious than that metal ; very ductile and malleable ; affords fine wire and thin leaves ; tasteless and inodorous, even in vapor ; susceptible of a fine polish.

* Ann. of Phil. XIV, 269, 435 ; XV, 272, and N. S. III, 123. Henry. Ann. de Chim. et de Phys. XI, 76, and XXI, 217.

† To dissolve any zinc or copper that may have been thrown down by the sulphuretted hydrogen.

‡ Ann. de Chim. et de Phys. XXI, 218.

(b.) Texture compact; *sp. gr.* 8.604, and *after hammering*, 8.694;* *melts below redness*, and *even rises in vapor almost as readily as mercury*, and condenses in brilliant crystalline drops, resembling that metal, except that they are solid.

(c.) In becoming solid from a state of fusion, *crystallizes in fern-like leaves*, and by slow cooling, can be obtained in *regular octahedral crystals*. It soils bodies against which it is pressed, and is easily cut by a knife.

(d.) *Not altered by the air, nor by oxygen gas, unless heated*, when it burns as readily as tin, emits light and affords an oxide in *brownish yellow fumes*; the hydrate is always colorless.

(e.) *There is only this one oxide*, whose composition is 56 metal, and 8 oxygen; 56 is therefore considered as *the equivalent of cadmium*; it is irreducible and fixed in the most intense fire.

(f.) *Soluble in ammonia, but not in its carbonate*; nor in potassa or its carbonate, and these even precipitate it from its solution in ammonia; in this manner Mr. Children separated it from the oxide of zinc, which is not thrown down by the fixed alkalies.—H.

IV. ITS SALTS.—*The oxide of cadmium attracts acids powerfully, and forms distinct neutral salts*, which have the following general characters.

(a.) They are *colorless*, have a *sharp metallic taste*, and are *generally soluble* in water.

(b.) *The fixed alkalies precipitate the oxide as a white hydrate*, and do not dissolve it when added in excess, as is the case with oxide of zinc.

(c.) *Ammonia precipitates a white hydrate, and in excess redissolves it*.

(d.) The alkaline carbonates throw down a white anhydrous carbonate, while that of zinc is hydrous.

(e.) *Sulphuretted hydrogen throws down cadmium*, from its solutions, *of a beautiful yellow color*, like orpiment; and *this is one of its most characteristic properties*; but there is no change with chromate of potassa, infusion of galls, or sulphate of soda.

1. *The sulphate* crystallizes in large rectangular prisms; efflorescent, very soluble, contains more than one third of water. The neutral sulphate consists of 100 acid, + 161.22 oxide.

2. *Nitrate*—in acicular prisms or needles—deliquescent; constitution, acid 100, + 117.58 oxide.

3. (a.) *Muriate*—made by dissolving the oxide in muriatic acid; crystallizes in small transparent rectangular prisms—efflorescent.

(b.) *Chloride*—by heat, the crystals of muriate lose their water of crystallization, and pass to the condition of chloride; *fusible below*

* 8.67 before—9.05 after being hammered.—Children, Eng. Quar. Jour. VI, 226.

ignition; by an increased heat, sublime in small transparent laminae of a pearly lustre; constitution of the fused chloride, 38.61 chlorine, + 61.39 metal.

4. *The carbonate*, produced by the alkaline carbonates, is pulverulent, and insoluble in water; decomposable by heat; composition, acid 100+292.88 oxide.

5. *The phosphate*, produced by the phosphate of soda, also pulverulent, and insoluble; composition, acid 100+225.49 oxide.

V. OTHER COMPOUNDS.—1. *Sulphuret*, formed either by heating sulphur with the metal, or with the oxide,* or by precipitating the metal, by sulphuretted hydrogen, from an acid solution: composition, 100 metal, to 28.172 sulphur, corresponding to the equivalents 56 metal, and 16 sulphur, and there is only one sulphuret.

Color, orange yellow, of great beauty; resembles orpiment, but is distinguished from it by being readily soluble even in cold mariatic acid, and insoluble in potassa, and by sustaining a red heat without decomposition; the color is changed by heat, first to brown, and then to carmine red, but on cooling it becomes yellow again; exists native, in the cadmiferous ores of zinc; the great beauty of its color will probably introduce it into painting.

2. *Phosphuret*, formed by fusion; color, gray; lustre, feebly metallic.

3. *Iodide*; formed both in the moist and dry way; in tabular crystals, large and beautiful, colorless and transparent, of a metallic or pearly lustre, not altered by the air; very fusible, and cools without alteration; the iodine is expelled by a stronger heat; composition, metal 100+iodine 227.43; soluble in water and alcohol.

4. *Alloys*.—Cadmium forms brittle and colorless alloys with most of the metals, but they are little known. Its amalgam is easily formed even in the cold; it is of a beautiful silver white, and crystallizes in octahedra, composed of 100 mercury, and 27.78 cadmium; it is hard and fragile, and its sp. gr. is greater than that of mercury. The alloy with cobalt is white like arsenical cobalt.

Remarks.—It is obvious that Cadmium is an interesting metal, but it is entirely unknown in the arts, except that it is now ascertained to be evolved from some of the ores of zinc during their reduction, and Mr. Herapath thinks it may be supplied at a cheap rate, if the fume, called the brown blaze, which comes over first, and is wasted by the workmen, were collected by a tube, for this contains the cadmium in the greatest abundance.† I am not aware that cadmium has been obtained in this country; probably the great quantities of zinc

* The process with the oxide is much the easiest.

† Ann. de Chim. et de Phys. V. XXI, p. 219.

ore which, according to the observations of Messrs. Troust and Le Seur, are thrown away at the Missouri lead mines, would afford abundance of both metals.

There can be no doubt that the polarity of cadmium in the galvanic circuit, is negative, although I believe it has not been subjected to trial in this respect.

SEC. XXVII.—BISMUTH.*

I. NAME AND HISTORY.—The old name, tin-glass, is a corruption, as is said of the French *étain de glace*, (tin for silvering glass,) as bismuth is used for that purpose along with quicksilver and tin. So it is stated that bismuth is a corruption of the German weiss-muth or white mother of silver, the metal being so called by the German miners.—Gray.

Mentioned by Agricola, in 1520, but confounded with tin and other metals.† Early in the 18th century, believed to be a peculiar metal, and its properties were well distinguished in 1753, by Geoffroy, Jr.‡

II. PROPERTIES.

- (a.) *Color white, with a shade of red or yellow;*
- (b.) *Foliated and brittle like antimony; structure, in brilliant plates, but it is much heavier than antimony which is bluish or grayish, not reddish white.*
- (c.) *Sp. gr. 9.82, or even 10.00, if pure and condensed by pressure.*
- (d.) *Breaks under a violent blow, but is a little flattened first; can be pulverized by the anvil or in a mortar; can be passed through a sieve; powder of a dirty gray. Thin plates of it are a little sonorous.*
- (e.) *Easily cut, being a little harder than lead, nearly as soft as copper.*
- (f.) *Not malleable or ductile; among metals, an imperfect conductor of heat. Not elastic; almost tasteless and inodorous.*
- (g.) *Very fusible; it melts at 476° Fahr., sooner than antimony or lead, nearly as soon as tin; runs the thinnest of all the metals; in congealing, it expands contrary to the usual law in such cases, and therefore takes, with the greatest delicacy, the finest impressions of the mould.§*

* Olim, tin-glass.

† Its real nature was not understood, and hence, at various periods, it received names denoting its supposed origin from tin, lead and antimony, and the German miners seem to have regarded it even as an incipient silver, for they called it *lectum argenti*.—See Four. V, 266 and 267.

‡ Memoirs of the Paris Academy.

§ It may be poured, in the fused state, into a cone of paper, without burning or even scorching it.

(h.) *By slow cooling after fusion, it crystallizes in parallelepipeds or cubes,* joined at a right angle.* Häuy extracted the octahedron from the cube.

(i.) *Volatilized at 30° W., although covered with charcoal; in close vessels, it rises in vapor and may be thus distilled, when it crystallizes in filaments.†*

III. RELATION TO OXYGEN.—(1.) COMBUSTIBILITY.

(a.) *Unaltered by a dry, but tarnished by a moist air; in fusion, it soon becomes covered with a gray pellicle; a mixture of metallic bismuth and oxide.*

(b.) *At ignition, it burns with a faint blue flame, and a yellowish smoke, which is the oxide of bismuth.*

(c.) *Bismuth, when in combustion, stains the charcoal support yellow, while antimony stains it white.*

(d.) *All these phenomena are much more conspicuous with the compound blowpipe, in whose focus the bismuth boils, evaporates and burns vehemently; if, after it is kindled in the compound flame, the hydrogen be shut off, it continues to burn, splendidly, in the oxygen gas alone.‡*

(2.) OXIDE.

(a.) *The yellow oxide, which rises in the combustion of this metal, was formerly named flowers of bismuth.§ There is only one oxide.*

(b.) *It may be formed by combustion, but more conveniently by the action of nitric acid.*

(c.) *Its composition appears to be bismuth 72, and 8 oxygen—one equivalent of each.|| It is found in small quantities as a natural production.*

* When the bismuth, melted in a covered crucible, and then cooling, is fixed at its surface, we perforate the crust, and pour off the fluid portion; or, better, after giving it a good heat to expel arsenic, it is poured into a warm plumbago crucible, having a lateral hole stopped by a wooden peg; when the metal has set at top, the peg is to be withdrawn, and crystals will generally be found in the interior.—Gray. It crystallizes more easily than any metal, and was the first that was made to undergo this process.—For an improved mode of crystallizing bismuth, see Aikins' Dict. Vol. I, p. 137. It crystallizes in very perfect cubes from its solution in mercury.

† Formerly denied; Thénard says, (5th Ed. Vol. I, p. 399;) "Quoique regardé comme volatil par quelques chimistes il n'est réellement pas; du moins, lorsqu'on le chauffe très fortement dans une cornue de grès, on n'en trouve point dans le col après l'opération."

‡ When bismuth is used instead of lead in assaying silver, and the heat is too suddenly raised, globules dart out on every side, burning with a very brilliant flame.

§ Probably in allusion to the pollen of flowers, a similar name was given to the oxides of several other metals, that rise in a current of hot air, e. g. flowers of antimony, flowers of zinc, &c.

|| J. Davy, Thomson.

(d.) *This oxide easily melts, at ignition, into a yellowish glass, and is promptly reduced when heated with charcoal.** It may be sublimed.

IV. COMBUSTIBLES.

1. *Phosphorus ; the phosphuret is little known and of no importance.*

2. *Sulphur, by fusion, unites with bismuth, at a degree of heat much higher than its melting point ; 3 parts of the metal are mixed with one of flowers of sulphur. The sulphuret is gray, and crystallizes in acicular tetrahedral prisms.†* Its composition is, bismuth 1 equiv. 72 + 1 of sulphur 16 = 88 its equivalent. It is said that there is a bi-sulphuret.

V. ACIDS.

1. *With sulphuric acid, in the cold, there is no action, but, at ebullition, it converts bismuth into a white oxide, sulphurous acid gas being disengaged.‡* By evaporation, small needle crystals of sulphate are obtained, but they are decomposed by water, and the oxide is precipitated.

Composition.—1 equiv. of bismuth 72, + 1 of oxygen 8, = 80 + 1 of acid 40, = 120, its equivalent.

2. Nitric acid.

(a.) *When concentrated, it attacks bismuth with great heat and violence ; nitric oxide gas is copiously evolved,§ and a white oxide is formed.*

(b.) *To obtain a colorless solution of the nitrate, we take acid 2 parts, water 1 or 2, adding the metal by pieces, at intervals, till the action ceases.*

(c.) *Transparent oblique rhombic crystals are easily obtained, often even without evaporation. They are white and are frequently acuminate by three or four planes.*

(d.) *This nitrate detonates feebly on red hot charcoal, or when triturated with phosphorus ; by heat alone, it leaves a yellowish oxide.*

(e.) *Precipitated oxide, &c.—Either the crystals, or the solution, with a profusion of water, precipitate the white oxide, or the sub-nitrate. The water takes nearly all the acid, but the oxide retains a*

* From the easy fusion of the oxides of bismuth, they have been sometimes used in cupellation.

† This crystallization is effected, in the usual manner, by piercing the congealed crust, and pouring out the fluid below. The cavity is lined with the most beautiful needles, and a section of it presents a crystalline mass, worthy of being placed in valuable collections among the most beautiful productions of art.—*Four.*

‡ Even sulphur is sometimes sublimed, if the heat is considerable.

§ It is said that even sparks of fire have sometimes been observed darting through the mixture.

little.* It must be washed and agitated repeatedly, in much water, and dried in the dark, away from foetid gases.†

It is said that if a little muriatic acid be added to the nitric, and the precipitated oxide is washed with a little cold water, it will appear in minute scales of a pearly lustre, being the pearl powder of the perfumer.‡ The white cosmetic of bismuth is called by the French, *blanc de fard*.

(f.) This nitrate, of moderate strength, is used as a sympathetic ink; we may write on a card, and expose it to hydrogen or sulphuretted hydrogen gas, when the letters will appear.§ If we write with moderately strong nitrate upon paper, the traces will be invisible when dry, but appear of a dense white on being moistened; on a colored paper they will of course be the most distinct.

(g.) The oxide of bismuth is a valuable medical preparation; used particularly in pyrosis, cardialgia, and other forms of dyspepsia; dose, from 1 or 2, to 6, or even 12 grains per diem, repeated two or three times; it is made into a pill with 4 or 5 parts of gum arabic, sugar or starch.||

3. (a.) Muriatic acid dissolves the oxide, but acts feebly on the metal, even when in small grains, and aided by heat. But the nitromuriatic acid readily oxidates and dissolves it, producing a muriate.

* This precipitated oxide was formerly called magistery of bismuth, and is known in commerce by the appellation of *pearl white*.

† Formerly used as a cosmetic, but it injured the skin, and it was liable to become dark by contact of any putrid effluvia, containing usually hydrogen, sulphur or phosphorus—as from boiled eggs, sulphureous waters, sewers, &c., and even from the animal transpiration. Pomatum mixed with it, turns the hair black, (Chap.) and even sitting before a fire of mineral coal will tarnish the face, if whitened with this substance.—Parkes.

‡ Dr. Black says, that the old magistery of bismuth used as a cosmetic, is a precipitate from a nitrate, by a solution of common salt, or of tartar, as water alone leaves so much acid with the oxide as unfits it for any such use. Most or all the elementary books are, however, against this opinion.—See Four. Vol. V, pp. 283-4; Accum, Vol. II, p. 54; Chapt. p. 305; but Murray supports it, Chem. 1st. Ed. Vol. III, p. 461.

§ Ure.

|| Sulphuretted alkaline hydro-sulphurets being added to a solution of bismuth, there is instantly a precipitate of a hydro-sulphuret of bismuth, of a dark color.

¶ Formula:—bismuth, 1 oz.—nitric acid, 1 1-2 fluid oz.; distilled water, three pints; dilute the acid with 6 fluid oz. of the water, and dissolve the bismuth; filter, decompose the solution by the remaining water; allow the matter to subside; wash it and dry it in bibulous paper, with a gentle heat. This oxide on charcoal, especially with the addition of a little grease, is easily reduced by the blowpipe, and the reddish tinge of the metal, its greater weight, and its staining the charcoal yellow instead of white, when it is again burned by the blow-pipe, will distinguish it from antimony. The medical effects of the antimony are also violent, while those of the bismuth are mild. The solution of bismuth is decomposed by water, rather than by an alkali, because the latter would precipitate lead if it were present, and this would make the preparation a poison; lead is not thrown down by water. No metallic oxide is so decidedly precipitated by water as that of bismuth, and this is therefore a good criterion of the presence of this metal.

country, with native silver, argentiferous galena, blende, tungsten, &c.* this is the only known American locality.

Native bismuth is easily distinguished by its brilliancy, and by its melting with the heat of a taper.

XII. EXTRACTION.—*Bismuth is easily obtained, by heating the ore in a closed crucible*, with one eighth part of flux. The bismuth of commerce being dissolved in nitric acid, and the oxide precipitated by water and made into a paste with oil, and black flux, is rapidly reduced in a closed crucible, when we would obtain it pure.

In the large way, fragments of the ore are thrown upon wood fuel burning over a small pit. The oxidized bismuth passes through the coals, is reduced, and collects in the cavity, in orbicular cakes; or, over a hole dug in the earth, they incline the trunk of a fir tree, split in two and hollowed into a channel, upon which a bed of dry wood is fired, and the ore is thrown upon it; the metal runs along the channel and is collected in the hole, whence it is dipped in ladles and cast into ingots in iron moulds.†—*Fourcroy*. It is reduced also in cast iron tubes laid inclined in a furnace; the upper end being stopped, the metal flows out at the lower end; it is melted also in covered crucibles in a reverberatory furnace, and the metal subsides through a hole in the bottom of the crucible.

The bismuth should always be strongly heated to expel arsenic, and if any should remain, it will be discovered by a deposition of arseniate of bismuth after digesting the metal in nitric acid; if pure, it will be entirely dissolved.—*Thenard*.

XIII. POLARITY—negative.

SEC. XXVIII.—TIN.‡

I. HISTORY.—*Known from the highest antiquity; mentioned by Moses.*§ The Phenicians transported it from Spain and Britain.|| The Egyptians, Greeks and Romans knew many of its uses. As tin has a splendid appearance, like the planet Jupiter, the alchemists called it after that metal, and its preparations were named Jovial.¶

II. PROPERTIES.—*Tin is obtained pure by boiling it in nitric acid, and the oxide, which spontaneously precipitates, is reduced by charcoal in a crucible.*

* Am. Jour. Vol I, p. 316.

† For a particular account of the process used at Schneeberg, Saxony, see Gray's Op. Chem. 737. Bismuth is often extracted from the ores of cobalt.

‡ Olin stannum and Jupiter.

§ Num. xxxi, 22.

|| Passing the pillars of Hercules and going to Britain, the Ultima Thule, a great voyage in those days.

¶ For they blended astrology with chemistry; and the metals and planets being then equal in number, each planet had a metal, and each metal a planet.

- (a.) *Color brilliant white, almost equalling silver in splendor.*
 (b.) Sp. gr. 7.299.* Since all those metals with which it is apt to be adulterated, (e. g. lead,) are heavier, its sp. gr. is a test of its purity.
 (c.) *Emits a peculiar odor, by friction and handling; taste slightly unpleasant.*
 (d.) *Readily cut by a knife, impressed by most of the metals, scratched even by the nail.*
 (e.) *Flexible, and in bending, gives a peculiar crackling noise, formerly called the cry of tin.†*
 (f.) *Only slightly elastic and sonorous.*
 (g.) *Very malleable, as appears in tin-foil,‡ $\frac{1}{8}$ of an inch thick, and it might be reduced to $\frac{1}{100}$.*
 (h.) *Very little ductility and tenacity; a wire $\frac{1}{8}$ of an inch in diameter,§ will not support more than 37 pounds.*
 (i.) *Very dilatable by heat, and one of its best conductors.*
 (j.) *Melts at 442° || Fahr.; more fusible than any metal except potassium, sodium, and mercury, and stands immediately before lead and bismuth.*
 (k.) *May be imperfectly crystallized in the usual manner, in rhombs, composed of octahedra.¶*
 (l.) *Vaporized by the intense heat of the compound blowpipe, but fixed in close vessels.*

III. RELATION TO OXYGEN.—*But slowly altered by the air, either moist or dry; it preserves its splendor for years, but is eventually tarnished.*

* According to the French authorities; Henry and the Aikins make it 7.9.

† As this probably depends upon the sliding of the crystalline plates upon each other, and as foreign metals would diminish this effect, it is regarded as a test of the purity of tin.

‡ The process for making tin-foil consists simply in hammering out a number of plates of this metal, laid together upon a smooth block or plate of iron—the smallest sheets are the thinnest.—*Ure's Dict.*

Tin-foil is made from the very finest tin, which is first cast into an ingot, then laminated to a moderate extent, and afterwards beat out with a hammer, with great manual labor and skill, till it is brought to the requisite thickness.—*Aikins' Dict. Article Tin.*

To prepare tin of the greatest thinness, the leaves are beaten between those that are thicker, and thus we avoid tearing them; thus the leaves are prepared in which chocolate is wrapped.—*Laugier.*

§ Thénard, I, 170.

|| Crichton, Phil. Mag. XV, 147.

¶ If struck while concreting, it forms *grain tin*; if melted in an iron mortar, and stirred briskly and incessantly until it is congealed, we obtain the pulvis stanni or powder of tin, of the dispensatories.—*Black.* Or, it may be poured into a wooden box chalked on the inside; by agitation, it is granulated, and the chalk is removed by washing.—*Aikins.*

OXIDES.—*Fused and agitated in contact with air, tin is converted into a gray oxide,* and the whole may be removed in successive pellicles.†*

1. *Protoxide.*—*There are two oxides of tin, and the above is the protoxide.*

(a.) *It is also precipitated from the proto-muriate of tin by potassa, without excess, or its carbonate, and is washed and dried away from the air, as it is prone to absorb more oxygen.*

(b.) *It is obtained by placing, in the cold, tin filings in contact with nitric acid, 1 part, and water 10; they remain for 48 hours together; there is very little effervescence, and the tin becomes protoxide, little liable to be altered by heat and air.—H.*

(c.) *Composition.*—Tin 58, one equivalent, + oxygen 8, one equivalent = 66 its equivalent.

(d.) Insoluble in water, and by being ignited, it takes fire and burns like under; it is not a natural production.

2. *Deutoxide.*

(a.) *It is obtained also by heating and stirring the gray oxide till it becomes white.*

(b.) *Better, by corroding tin by diluted nitric acid, when a white substance separates, which on beingedulcorated and ignited, affords a yellowish peroxide.*

(c.) *It is white, fusible, and decomposable by heat; reduced by galvanism, and is not acted upon by the air.*

(d.) *Composition.*—Tin, 1 equiv. 58, oxygen two = 16 = 74 its equivalent.

(e.) *In the arts, called putty of tin, and is used to polish steel, specula for telescopes, and other hard bodies;‡ with oxide of lead, to give*

* Itinerant artists, in repairing pewter and tin utensils in families, it is said, were accustomed thus to convert a large part of the melted metal into dross, which, taking it for their own, they could afterwards reduce, by heating it with combustibles.

† Which should be rubbed in a mortar with water, and the latter decanted to remove metallic particles.

‡ It is made in the large way by calcining tin, and agitating it a good while in contact with the air: the substance is powdered, sifted, and recalcined in a muffle, with increased heat, until it is sufficiently white and hard.

It is a striking point of analogy between the earths and the common metallic oxides, that the latter are, in any instance, capable of equalling or rivalling even silica and alumina in the firmness and sharpness of their integrant molecules; tin, iron, and even zinc, are remarkable in this way, as is seen in their well known use, in polishing and sharpening delicate steel instruments.

The finest putty is made from the best tin, but pewter or a mixture of tin and lead is often used, as it is oxidized with more facility; it even takes fire when heated.

The glazier's putty is made of whiting and oil; formerly it contained white lead which is now omitted.

glass a milky opacity, and to form a white enamel; if the oxide of lead is not added, the glass is transparent.*

3. Combustion of tin.

(a.) *Melted and vigorously heated*, even by the mouth blow pipe, and being thrown, when in high ignition, upon the floor, it emits brilliant and beautiful sparks and burning globules.

(b.) *Strongly ignited in a covered crucible, and the cover and film of oxide being suddenly removed; it starts out in luminous jets*, with a lively white flame, similar to that of zinc; a white oxide is thus produced.

(c.) But it is in the focus of the compound blow pipe that it burns with the most intense splendor, and with the emission of a copious white cloud of oxide,† which rises mechanically in the current of hot air.

After the tin is fully ignited, the hydrogen may be shut off, and the metal will burn in the stream of oxygen with additional energy.

4. *Not affected by immersion in water*, but steam, passed over red hot tin, is decomposed, and hydrogen gas evolved, while the tin is oxidated.‡

IV. COMBUSTIBLES.

Tin combines with only two of the simple combustibles, viz. sulphur and phosphorus.

1. *Sulphur: there are two sulphurets of tin.*

(a.) *Protosulphuret.*

Mix, heat, and agitate the two bodies in a crucible or ladle: or throw 1 oz. of sulphur upon 5 of melted tin, and stir them; they will become ignited, from the emergence of latent heat and light, presenting an appearance of combustion.

(b.) *Properties.*—*Less fusible than tin; color bluish, and metallic; structure lamellated, and crystallizable in needles or cubes.*

(c.) *Composition.*—Tin, 1 equiv. 58+1 of sulphur 16=74 its equivalent.§

2. *Bisulphuret.*—*Aurum musivum.*

(a.) *When equal parts of white oxide of tin and sulphur are mixed and heated gradually in a retort, sulphur and sulphurous acid rise, and the heat being increased to redness, and maintained for some time, beautiful light adhesive gold colored flakes are obtained.*

* Dr. Black.

† The oxide of tin, especially when formed by the nitric acid, has been regarded by some as being itself an acid, and it was called *stannic acid*, but the affinity for bases is too feeble to justify this arrangement, and it has no other acid property.

‡ Ann. de Chim. XXXV, 28, quoted by Th. I. 171.

§ As, from the heat necessary to the union, there is apt to be a deficiency of sulphur, the sulphuret formed in this manner is contaminated with metallic tin, and it is now formed preferably from the bisulphuret, which see.

(b.) To melted tin* 12 parts, add 3 of mercury; with the powdered amalgam, mix 7 parts of sulphur and 3 of muriate of ammonia, to the mixture apply heat in a covered crucible, till the white vapors cease; the heat is then moderately increased, and the bi-sulphuret, or aurum musivum, remains at the bottom.

(c.) *The bisulphuret of tin is not affected by acids, while the sulphuret is decomposed*: it is tasteless and insoluble in water. Its composition is 58 tin, 1 equiv. + 32, (2 equiv.) sulphur=90 its own equivalent.

(d.) *Used to give, by friction, a golden color to bronze,† and japanned work, and to excite electrical machines.*

(e.) *A nice regulation of the heat is indispensable to success*;—if too low, the bisulphuret is not formed; if too intense, it is decomposed and simple tin remains.

A sesqui-sulphuret, consisting of tin, 1 equiv. 58 + 1½ of sulphur 24=82, has been formed by Berzelius, by heating to low ignition the bi-sulphuret with sulphur.

(f.) *Sulphuretted hydrogen precipitates tin from its acid solutions*; yellow from salts with peroxide, dark coffee colored from those with protoxide.

2. Phosphorus.

Phosphuret of tin may be formed in the usual manner; it is *silvery white, with a foliated texture*, soft and little malleable.

V. ACIDS, in general, do not form permanent compounds with tin; which is prone to separate from them in the form of an oxide.

1. Sulphuric acid.§

(a.) *When strong and cold, the action is tardy and feeble, almost inert.*

(b.) *Acid 3 and water 1, the tin in filings, heat being applied, the action is rapid, the metal¶ is peroxidized, sulphurous acid is evolved, ½ as much metal as acid is taken up, and needle crystals may be obtained. When the mass is evaporated to dryness, it is partially decomposed by adding water, and sub-sulphate of tin is deposited.*

2. Nitric acid.

(a.) *When cold and concentrated there is no action*; a strip of tin-foil may be kept in a bottle of the acid for years, without being cor-

* Chaptal's proportions—8 oz. tin + 8 mercury, 6 of sulphur and 4 of muriate of ammonia. The sole use of the sulphur appears to be to enable us to pulverize the tin; the sal ammoniac is probably useless, and strictly, all that is necessary is oxide of tin and sulphur. For a great variety of processes see Aikin's Dict. II. 432.

† It is also used by japanners for many articles intended to have the appearance of metallic gold; (Accum. II. 99): and to adulterate copper bronze powder, an article used by Japanners.—G. C.

§ Pewter vessels answer very well, for obtaining hydrogen gas with diluted sulphuric acid and zinc or iron; and even tinned iron will last for some time.

¶ Even sulphur is disengaged if the heat be very long continued.

roded, provided the air be excluded;* but, if diluted with water, the action is immediate and violent, and the metal is peroxidized, and converted into a white mass, while nitric oxide gas is disengaged.

(b.) *With acid of the sp. gr. 1.14, some of the tin remains in solution, but it separates by heat; if it is of sp. gr. 1.25, the tin all separates, as a white oxide.*

(c.) Tin dissolves, slowly and without effervescence, in nitric acid largely diluted, but by keeping, a yellow oxide spontaneously falls.

(d.) *During the solution, nitrate of ammonia is formed; the acid and the water each affording one of its elements.†* It is disengaged by rubbing the materials with quick lime.

3. Proto-muriate of tin.

(a.) *Muriatic acid in its usual state, with a gentle heat, dissolves one third‡ of its weight of tin with facility, decomposing water, and emitting a peculiar fetid hydrogen gas.§*

(b.) *Proportions, metal 1, acid 2, in a tubulated retort or flask; the solution is complete except a little black powder, which is peroxide of copper; the acid ceases fuming when it dissolves tin.*

(c.) *The muriate of tin in this case, contains the protoxide: it must be kept from the air or it will pass to the state of peroxide; a little metallic tin in the vessel tends to preserve it as a proto-muriate.*

(d.) *It has so strong an affinity for oxygen as to absorb it from a variety of bodies; viz. from common air, nitric acid, arsenious acid, and from red oxide of mercury, the black oxide of manganese, the white oxide of antimony, the oxygenated salts of iron and copper, the muriate of gold and of platinum, and the oxides of zinc and silver, and from many other things; passing at the same time to the state of muriate of peroxide, while the oxides and salts are either metallized, or brought to a minimum of oxidation.*

(e.) *The solution of the recent muriate of tin is limpid, and yields, by evaporation, oblique four sided prisms, which are deliquescent and acid; sp. gr. is 2.29; precipitated black by the alkaline hydro-sulphurets.*

(f.) *Composition, acid 1 equiv. 37, protoxide 1 equiv. 66, and water 1 equiv. 9=112. There is a sub-muriate with 1 equivalent of acid, 2 of protoxide and 2 of water.*

* First mentioned by the late Dr. Woodhouse, of Philadelphia, at the time when I was his pupil, in 1802, 3, and 4. I have kept tin-foil in a bottle of the strongest nitrous acid for years, without any action, the tin remaining bright.

† Can this be one of the reasons why strong nitric acid does not act upon tin, namely, that there is nothing to afford hydrogen?

‡ Dr. Ure says one half.

§ Mr. Proust ascribes it to arsenic, but as it is emitted equally by the purest tin, it probably arises from a suspension of some of the metal.

(g.) *Muriate of tin* is extensively used in calico printing, for discharging and altering colors.—(A. A. H.)

Permuriate of tin.

(a.) *Pass chlorine gas through the solution of the proto-muriate of tin*, expelling the excess of the gas by heat. In this case, water yields its elements, the oxygen to the metal, and the hydrogen to the chlorine. The crystallized permuriate is composed of peroxide, 1 equiv. 74; acid 2, =74, and water 3, =27=175, its equivalent.

(b.) *Dissolve tin in nitro-muriatic acid*, mixed in the proportion of 3 parts of muriatic to 1 of nitric acid; the metal is added in separate pieces, checking the action by immersing the vessel in cold water; thus the compound acid will take up about half its weight of the metal.

(c.) *Commonly made by the dyers, by using 8 oz. of double aquafortis with the addition of 1 or 2 oz. of common salt or sal-ammoniac.* The solution varies in its properties and is sometimes a proto- or others a per-muriate and frequently a mixture of both.* It takes up about one $\frac{1}{8}$ of its weight of tin. This solution, combined with tartar, is used to give the scarlet or flame color to a decoction of cochineal, which, without them, is of a crimson hue, inclining to violet.†

(d.) *It is probable that the muriate of tin, made by muriatic acid alone, is in the best state for the dyer*; for it abstracts oxygen so eagerly from the air, that it will pass rapidly to the state of per-muriate; and it is said that in dyeing with it, the mere passage of a cloud over the sun will alter the shade of color.

VI. *Chlorides.*

1. *Proto-chloride.* It may be formed by heating an amalgam, of tin and mercury, with calomel, and expelling, by heat, the undecomposed calomel and reduced mercury; its solution in water is limpid, and is nothing else than muriate of protoxide or proto-muriate.

2. *Deuto-chloride or perchloride.*

(a.) *Long known under the name of fuming liquor of Libavius,‡* An amalgam§ of two parts of tin and one of mercury, triturated with as much corrosive sublimate, and gently distilled in a retort;|| or 8 oz. powdered tin distilled with 24 oz. corrosive sublimate.

* Hence the dyers find that different solutions of tin give different shades of color, with cochineal, lac, &c. this would probably be remedied by forming the proto-muriate first, and then saturating it with chlorine gas. A solution made with 14 oz. of tin, 2 lb. of sulphuric acid, and 3 of muriatic, is equally good and is much cheaper. Tartar is necessary to the development of the fine color of cochineal.—*Dr. Bancroft.*

† As a mordant, the muriate of tin, along with some tartar, is dissolved in much water, and the cloth is dipped into the solution and allowed to remain till it is sufficiently saturated. It is then taken out and washed and dried. A beautiful red ink may be formed by tinging the tincture of Brazil wood, with the nitro muriatic solution of tin.

‡ A chemist of the sixteenth century.

§ Amalgam of 6 of tin, +1 of mercury, +80 corrosive sublimate.—(H.)

|| The amalgamation is of no importance except to divide the tin and render it pulverulent.

(b.) *Product.*—First, a colorless fluid, then suddenly and almost explosively, a thick vapor, which condenses in the receiver into a liquor that smokes in the air, but not in close vessels.

This is a dry perchloride of tin, and the smoking arises from its attraction for the water of the air.

(c.) *Chlorine gas inflames tin filings when thrown into it*; they burn with a bluish white flame, and the product is a deuto-chloride; the same that is formed by the indirect process of Libavius.

(d.) *Aqueous solution of chlorine readily dissolves tin without effervescence*, and forms a muriate; the proto-muriate of tin precipitates gold of a purple color from its solution, forming the purple precipitate of Cassius; but the permuriate does not precipitate it because it is saturated with oxygen.

VII. *Iodine combines directly with tin* by heating them together; or, solution of hydriodic acid or of a hydriodate added to the solution of proto-muriate of tin, affords an orange precipitate.

VIII. *ALKALIES.*—Concentrated solution of potassa, soda, or ammonia boiled on tin filings, or tin foil, dissolve a little which is thrown down by an acid. Ternary crystallizable compounds of acid, alkali and oxide of tin are sometimes formed; alkalies precipitate the solutions of tin—zinc decomposes them, forming a tree.

IX. *WITH THE EARTHS*, the oxide of tin, by fusion, oxide of lead being added, forms an opaque white enamel, and the same mixture is used to glaze earthen ware.

X. SALTS.

1. By heat, the sulphates are changed, by tin, into sulphurets.

2. The nitrates deflagrate with tin at a high temperature.

One part of tin filings with three of nitre, the mixture being thrown into a red hot crucible, produces a splendid deflagration; nitre wrapped in folds of tin foil and thrown upon the red hot coals, produces a similar effect.

3. The chlorate of potassa, 2 parts, mixed with 1 of fine tin filings, detonates by percussion, and deflagrates splendidly, on the hot coals.

4. Muriate of ammonia is decomposed by tin, (equal parts,) ammoniacal gas rises and muriate of tin results.

XI. *ALLOYS.*—Tin forms a part of many curious and useful alloys, most of them with metals not yet described.

1. Cobalt gives a granular alloy of a light violet color.

2. Bismuth, with tin, affords a brittle, hard, laminated mass; sometimes an ingredient in pewter, to which it gives whiteness and hardness.*

* Equal parts melt at 280°; 8 tin and 1 bismuth, at 390°; 2 tin and 1 bismuth, at 330°.

The muriatic acid will dissolve the tin, and leave the bismuth, as black powder.*

3. *Arsenic*—an alloy of 15 parts of tin to 1 of arsenic *crystallizes in large plates like bismuth*, but it is more brittle than bismuth, and less fusible than tin. The arsenic may be expelled by heat in the open air.†

4. *Zinc, with tin, produces a hard metal, of a fine close grain*; of which the ductility is greater, the more tin it contains; often the principal ingredient in pewter, zinc being, from economy, substituted for bismuth, to give it hardness, but more of zinc than of bismuth is required.

5. *The alloy of antimony and tin is white and brittle*, and is employed for plates, to engrave music upon; also, 17 parts of antimony with 100 of tin form an excellent pewter, and perhaps a still better is made with tin 100, antimony 8, copper 4, and bismuth 1.‡—Gray.

XII. POLARITY—*negative in the galvanic circuit.*

XIII. NATURAL HISTORY.—*Tin is a rare metal, at least in Europe.*

The only useful ore is the oxide, and no other is wrought. It is frequently crystallized in quadrilateral prisms, the color is brown and black, of many shades. The Cornish tin usually contains about $\frac{1}{3}\frac{1}{2}$ of copper, but hardly a trace of arsenic; and a groundless alarm, raised many years ago on the subject of arsenic in tin, has long since subsided.

The alluvial or stream tin is peculiar to Cornwall;§ it appears to have been washed and rounded by friction in water; it is usually fibrous in its structure, and has therefore been called wood tin.||

XIV. EXTRACTION.¶—*The dressed, picked and roasted ore is ignited with fine charcoal* in a reverberatory furnace; the carbon abstracts the oxygen, and gives the tin the metallic form.**

* Four. VI, 37. This alloy has the beautiful whiteness of fine silver, "and may be, and probably is used for ornamenting the iron work of chariots."—Bl. II, 680.

† Thénard, I, 232.

‡ Tin, alloyed with 3 per cent. of antimony, with a little copper, forms the best Britannia metal imported into this country, as I have found by its analysis.—G. C.

§ It is found in Siberia, Saxony, Bohemia and France, but the richest and most ancient mines perhaps in the world, are in Cornwall, England. These are less rich than formerly, and I found on visiting them, in 1805, that more copper than tin is obtained there. Tin is brought also from Banca and Malacca, and is particularly pure. It is said to be abundant in Mexico.

|| It is near Redruth, and would be called in geology a diluvial deposit; it is covered by 50 feet of clay, in which were found the antlers of a stag, a human skull, and a copper battle axe; in descending, the clay is succeeded by rounded stones, and then comes the tin, in a loose bed from one foot to five in thickness.—*Sikins' Dict.*

¶ For many curious facts respecting the varieties of tin in commerce, see Gray's *Operative Chemist*, p. 620.

** Each ingot is "coined" or assayed, and if of the proper fineness, it receives the stamp of the Duchy, paying four shillings to the Prince of Wales for every hundred weight. There is a local court for the decision of questions connected with the

XV. *USES*.—*These are familiar, and the history of the metal shows that they are numerous and important*, as in forming tin plate, in tinning copper and iron vessels, in making gun and bell metal, pewter, and *block tin ware*. The pipes of organs, music plates, tin foil, oxide of tin for polishing, and the muriate for dyeing—all these are examples of its utility.*

Tin takes oxygen from most of the metallic salts and oxides, causing them to precipitate either as metals or protoxides. Tin is therefore very useful in analysis.

The *pulvis stanni* is a feeble anthelmintic.†

SEC. XXIX.—LEAD.‡

I. *HISTORY*.—*Known from the remotest ages*; often mentioned by Moses. By the alchemists, called *Saturn*; and the derivative *satur-nine*, is still applied to some of its preparations.

To obtain it pure, the nitrate of lead was repeatedly crystallized, by Berzelius, till carbonate of ammonia indicated no copper; the nitrate was then reduced by charcoal. (H.)

II. PROPERTIES.

mines; it is held at Helston, and it is called the *stannary court*, and the laws are styled *stannary laws*. The average annual produce of the Cornish mines, anterior to 1806, when I was in that country, was 3000 tons. Great piles of blocks of stamped, or coined tin were lying in the public square in Truro, the capital of Cornwall.

* *Many beautiful ornaments of domestic furniture, are now made by crystallizing tin, as it is called*; it is effected by the action of the mineral acids upon tin plate.

1. Nitric acid 4 parts, common salt, or sal ammoniac 1, and distilled water 2.

2. Nitric acid 2, muriatic 1, water 2 to 4.

3. Nitric acid 1, muriatic 2, water 3.

4. Nitric acid 2, muriatic 2, water 2, sulphuric acid 2.

A sponge is moistened with one of these fluids, and applied on the tin surface; if the latter is warm, or the acid but little diluted, the effect happens in one minute; otherwise, in from 5 to 10 minutes. Cold water is then applied, and the surface washed with cotton or a feather, (never with the hand,) and it is allowed to dry. The acid should never be poured on, which would occasion spots.

Various figures are produced by laying the tin plate upon a red hot iron, while the acid is applied on the other side; and the use of the blow pipe forms in the same manner, stars and other beautiful figures, the perfection of which depends on the tact of manual dexterity, especially in washing at the proper moment; a second too soon or too late will spoil the effect. The washing should be done with river or distilled water, slightly acidulated with vinegar or a mineral acid, 1 oz. to 1 litre. A varnish, frequently a colored one, is applied over the surface.—*Annales de L'Industrie*, &c. tome II. page 17. The citric acid is sometimes used.

† It should be prepared from the pure tin; pewter often contains lead, rarely arsenic; still, an alarm, raised in France, as to arsenic in tin, produced a dissertation by Schultz, which he entitled "*Dissertatio de morte in olla*," alluding no doubt to the story of the sons of the prophets. While tin is almost as beautiful as silver, it is one of the most innocent of metals in relation to the animal economy.

‡ *Olim Saturn and plumbum*. The mythological allusion is said to be to the character assigned to Saturn, of devouring his children, as lead, in cupellation, absorbs all metals except gold and silver.—*Laugier*.

(a.) *Color bluish white*, when fresh melted or cut; *considerable lustre*, but much less brilliant than tin.

(b.) *Easily tarnished in the air*, and assumes the well known hue, called a leaden color.

(c.) *Easily cut*, by a knife, or scratched by the nail; softer than most natural bodies.

(d.) *Very little elasticity*; not sonorous by percussion; possesses little ductility.*

(e.) *Very malleable*; can be beaten into thin leaves; perfectly flexible.

(f.) *Imparts little taste*, but on friction, *emits a peculiar smell*.

(g.) *Sp. gr.* 11.352. In weight it is next below palladium, and next above bismuth and silver; it is lighter than iridium.

(h.) *It stains paper and the fingers, a bluish gray*.

(i.) *A very good conductor of heat*; not very dilatable.

(k.) *Melts at 612°.*† At full ignition, lead boils,‡ and passes off in noxious vapor.

(l.) *By very slow cooling,§ crystallizes in groups of quadrangular pyramids*.

(m.) *Lead may be granulated*, divided into shot, cast into balls, and extended into sheets. The granulation is sometimes effected by agitating the melted lead in an iron mortar, or stirring it with the pestle. Or, in an oval wooden box, chalked inside, and fitted with partial partitions, the melted lead, (the lid being on), is violently dashed and shaken, and is thus converted into grains.

(n.) *Bullets|| are cast in a mould, consisting of two hemispherical parts*, which open and shut like a nut-cracker.

Shot were formerly cast in the same manner, but it is long since they have been made, exclusively, by the mere gravitation and granulation of the lead.

(o.) This is not effected well, without the addition of arsenic.¶

* A wire, 1-10th of an inch in diameter, sustains scarcely thirty pounds, "but a rod of cast lead becomes nearly quadruple in strength by wire drawing." (Bl. II, 603.) Neither its sp. gr. nor hardness is increased by hammering, a fact peculiar to this metal.

† Crichton.

‡ November, 1826, I made it boil rapidly, on a ladle, in a charcoal fire, in a little earthen furnace, and abundant fumes arose, which were carefully avoided. On cooling, the surface was found covered with a beautiful yellow crust of fused massicot. The lead was left porous and vesicular, in consequence of the vapor of the metal being formed and condensed.

§ More especially after repeated fusions, (which is the case with tin also.)

|| If greater hardness is needed, bismuth may be added.

¶ About two per cent. of white or yellow arsenic is added to the soft pig lead, in an iron pot, which, protected by a tight cover, is heated red hot for three hours, and the quantity of lead is then doubled by fusion; trial is made by dropping it from two feet in height into water, and if the shot be not round, more arseniated lead is added, and the height increased from 10 to 150 feet, as the shot are to be coarser or finer.—Gray.

(p.) *Shot towers are erected to give the requisite elevation to the cul-lender, through which the melted lead streams, divides into metallic spray, is chilled in the air, and congealed or cooled in the water.**

(q.) *Lead is cast into sheets, by letting it run out of a box through a long horizontal slit at the bottom while the box is drawn along the table, leaving the melted lead behind it to congeal. The Chinese cast it extremely thin in this way on cloth for lining their chests of tea.†* Bl. II. 605. It is also rolled to give it the proper degree of extension and thinness. The melted lead is often poured on a flat stone, and another flat stone is dashed down upon it, by which it is pressed out into a thin sheet; the edges are trimmed, and the sheets are soldered together for use.—*Gray.* The sheets are from one twelfth of a line to three or four lines in thickness.

III. RELATION TO OXYGEN.

(a.) *Tarnished lead undergoes only a superficial change, and then remains nearly unaltered; or after a long time it becomes whitish, and eventually sheet lead is rendered brittle through and through.*

(b.) *Under the mouth blowpipe, lead is wasted away in a cloud of oxide, but without any thing very remarkable.*

(c.) *In the focus of the compound blowpipe, it burns with a brilliant white flame, and with an energy very nearly equal to that of tin; the fumes which rise, in a dense cloud, should be anxiously avoided, as they are very dangerous.*

(d.) *Fused in the air, a dull gray pellicle soon appears, and if removed as often as formed, the whole will be converted into a substance which is only a mixture of metallic lead and yellow oxide.‡*

IV. OXIDES.

1. Protoxide.

(a.) *If the grayish dross is heated in the air, to low ignition, it absorbs more oxygen, becomes first dull yellow, and is called common massicot, and by a higher heat, and longer exposure, it assumes a deeper yellow, and is then called massicot.§*

* The shot are not all regular, and to sort them, they are sifted on an inclined plane; the pear shaped grains deviate in curves to the right and left, while the round shot run straight down. A sort of funnel at the bottom divided by partitions, that conduct to different boxes, receives the descending grains; the middle boxes catch the round grains, and those on each side the irregular grains, good enough for low priced shot, while the worst are melted again, and the good are sorted into sizes by sieves.

† A small portion of tin is added to the lead used for this purpose; the thinnest sheets contain the largest quantity, and are used for enclosing the best teas; the surface of this compound is generally covered with acetate of lead.—A. A. H.

‡ I have already stated, that I have seen it formed in great beauty, and crystallized in laminæ, when the lead was in full ebullition. As in the case of tin, this dross, as it is called, is a good prize for the itinerant workmen, who know how to increase its quantity by frequent agitation and removal, and they know also how to reduce it by heating it with charcoal, &c.

§ Prepared also by heating red lead or nitrate of lead, to redness in a platinum crucible.

(b.) *Its composition*, is admitted as being lead 1 equiv. 104, + oxygen, 1 equiv. 8=112.

(c.) *Insoluble in water, melts at ignition*, unchanged by heat in close vessels—is the basis of the salts of lead, and is precipitated by alkalis from acid combinations, as a white hydrate; excess of potassa redissolves it.

(d.) *The litharge of commerce is the semi-vitrified protoxide of lead*, with about 4 per cent. of carbonic acid.

(e.) *Red lead, by suffering a partial fusion and vitrification*, and losing one half an equivalent of oxygen, assumes a glossy, sub-crystalline character and a reddish yellow color, and *becomes litharge*. By long exposure to air and to a moderate heat, it will reabsorb oxygen and become again red lead:

(f.) Or, *the yellow protoxide, heated so as to produce a partial vitrification, becomes litharge*, without previously becoming red lead. Thus, litharge is a kind of middle term between protoxide and deutoxide of lead, not however in the proportion of oxygen, but in the mode of aggregation and shade of color.*

2. Deutoxide.

(a.) *The protoxide or metallic lead, being heated in a reverberatory, and the flame playing upon the surface without causing it to melt, it will within forty eight hours, become the red oxide, the minium or red lead of commerce*;† when metallic lead is employed, it is first melted, then converted into yellow oxide, and then into minium.

(b.) *The minium‡ of commerce is not pure, containing sulphate, sub-muriate, and protoxide of lead, and silica*; the protoxide may be removed by acetic acid, which does not dissolve the red oxide.

(c.) *Most authors admit red lead as the deutoxide*, but Longchamp‡ regards it as composed of equal parts of tritoxide and litharge, soon to be described. Dr. Thomson§ considers red lead as a mixture of protoxide and deutoxide, sometimes with nearly half of the former. After the protoxide is separated by acetic acid, the real deutoxide has a dark red color, without the beauty of minium. The common minium is of a splendid red; by heat, it gives up a part of its oxygen, and passes to the condition of protoxide. Its composition appears to be one equivalent of lead 104, + $1\frac{1}{2}$ of oxygen 12, = 116.

* The litharge of commerce, being produced chiefly during the extraction of silver from lead ores, obtains its name of silver stone, (*λεθος αργυρον*), from that circumstance.

† Very beautiful red lead, can be produced only in the large way; the color produced in our laboratories, never rising higher than yellow; for the details of the manufacture of red lead, see Aikins' Dict., Gray's Op. Chem., and Thénard, 5th Ed. Vol. II, p. 387.

‡ Henry, and Ann. de Chim. et de Phys. 34, 104.

§ First Prin. I, 397.

It is thought that there is an oxide of lead with a smaller proportion than that in the protoxide ; if this should be established, it may remove the fraction between the deut- and tritoxide.

3. *Tritoxide*.—Processes.

(a.) *Formed by passing an excess of chlorine gas through water, containing oxide of lead*, suspended, or acetate of lead dissolved ; water yields its elements, the oxygen to the oxide of lead to form the tritoxide, and the hydrogen to the chlorine to form muriatic acid.

(b.) *The usual course is to mix red lead, 1 part, and nitric acid, 5 or 6, with as much water* ; one half the deutoxide gives half its oxygen to the other, which thus becomes tritoxide, and the protoxide remaining, forms with the acid, nitrate of lead ; this is diluted with warm water, and decanted, and the insoluble oxide washed in the same manner until it is tasteless ; it is then dried away from the air.

(c.) *Properties*.—Color brown, commonly said to be *puce or flea colored*, very fine and light, insoluble in nitric acid ; heated moderately, especially with the addition of sulphuric acid, it gives out oxygen and becomes deutoxide, and at a cherry heat, it emits more and becomes protoxide.*

Peroxide of lead triturated in a mortar with sulphur, bits of phosphorus being subsequently added, occasions a violent explosion. More chlorine is obtained by adding muriatic acid to this oxide, than to any other oxide of lead.

(d.) *Composition*.—Lead 1 equiv. 104, + oxygen 2 equiv. 16, = 120 ; thus, the numbers representing these three oxides are 112, 116, 120, and the oxygen is in the proportion of 1, $1\frac{1}{2}$, and 2 ; if we suppose a still lower oxide, containing one half as much oxygen as the protoxide, then all the above numbers will be doubled, and they will stand 2, 3, 4, but this has not yet been proved to be true.

Remarks on the oxides of Lead.

(a.) *They are all easily reduced, by ignition with charcoal*, (carbonic acid or oxide gas being formed,) or by hydrogen gas, heated in contact with them, by a burning lens, in a glass jar, or passed over them ignited in a tube, when water will be formed.

(b.) *Easily vitrified by heat*, oxygen is expelled from the deutoxide and tritoxide, and the resulting protoxide melts into a yellow glass.

* According to Proust, red lead is composed of protoxide and tritoxide ; the acid then, according to this view, dissolves the first and leaves the other.

(c.) *Litharge, ignited in an earthen crucible, makes its way through the bottom, and glazes it of a beautiful yellow, as I have repeatedly seen.*

(d.) *On account of their disposition to vitrify, especially with earthy bodies, the oxides of lead, especially litharge, are much used in glazing earthen ware.**

V. *WATER is not decomposed by lead; it has been supposed to be liable to dangerous impregnation from being kept in that metal, but it appears from the experiments of Dr. Christison,† that in pure water it is oxidized with considerable rapidity, carbonate of lead in white crystalline scales, being formed by the action of the oxygen and carbonic acid of the air; while saline matter, sometimes even in very minute quantity, prevents the corrosion of the lead, and that therefore many kinds of spring water may be safely kept in leaden cisterns.‡*

VI. *COMBUSTIBLES.—Lead unites with sulphur and phosphorus.*

1. SULPHUR.

(a.) *To 3 parts of melted lead add 1 of sulphur, and stir them; heat is evolved, sometimes even to incandescence, and a sulphuret is formed, a black scaly powder, which after fusion appears in facets like galena, and in chemical properties is the same.*

(b.) *Composition.—Lead 1 equiv. 104 + sulphur 1, 16 = 120, and when converted into sulphate, the acid and oxide exactly saturate each other. Hydro-sulphurets and sulphuretted hydrogen, precipitate the salts of lead forming hydro-sulphurets, and by heat, sulphurets.*

2. PHOSPHORUS.—Phosphuret.

(a.) *Formed by dropping phosphorus into melted lead, and quickly covering the crucible.*

(b.) *Or, by heating equal parts of lead filings and phosphoric glass with $\frac{1}{8}$ of charcoal powder.*

* Common red wafers are colored by red lead; if some ten or twenty of them are strung together on a wire, and held in a candle blaze, many minute globules of metallic lead will, by a little jarring, fall on a piece of white paper held beneath. The finest red wafers are colored by cinnabar, (sulphuret of mercury.) The oxides of lead are much used in painting, in forming flint glass, in glazing earthen ware, in forming sugar of lead, plasters, &c.

† Turner, 2d Ed.

‡ I have never been able to detect lead in any water drawn through leaden tubes; even the hydro-sulphurets of the alkalies producing no discoloration, and I have given this opinion when consulted as to the safety of lead in such cases, that there can be no danger, provided the tube or vessel be kept full of water, so as to exclude the atmosphere; for at the line of junction of air, lead and water, I believe there is always an action, probably galvano-chemical. It would however require strong evidence to prove that water strongly impregnated with saline and acid ingredients would not act upon lead, especially if the air had access. It is said that carbonate of lime dissolved in water, acts principally on the lead solder. In all cases where lead tubes and reservoirs are used to contain water, it should be occasionally examined by means of the hydro-sulphurets.

(c.) *Easily cut*—it breaks into laminae; the phosphorus is expelled by heat. Composition, 12 parts phosphorus, 88 lead.*

VII. ACIDS, unite only with the protoxide of lead, and not with the higher oxides; alkalies precipitate a hydrated oxide.

(a.) *The sulphuric; little or no action in the cold.*†

(b.) *With ebullition, the acid is in part decomposed*; the lead is oxidated, and an insoluble sulphate of lead is produced.

(c.) *More easily formed by adding sulphuric acid*, or any alkaline soluble sulphate, to the acetate or nitrate of lead.‡

(d.) *Properties.*§—*Insoluble in water*; slightly soluble in sulphuric acid; the super sulphate forms a few needle crystals by evaporation; *vaporized at a high temperature*: comparatively harmless, on account of its insolubility, and therefore a solution of sulphate of soda or of magnesia, or alum may be given as an antidote to lead poisons.

(e.) *Composition.*—

Protoxide 112 = lead 104 + 1 oxygen 8

Acid 40 = sulph. 16 + 3 " 24

152

per cent. acid, 26.34
oxide, 73.66

100.00

150 of the sulphate of lead represent a little more than 100 of the metal.

Sulphite of lead is of no importance.

3. (a.) *Nitric acid is the only proper solvent of lead.*

(b.) Somewhat diluted and heated, it dissolves lead readily, and emits nitric oxide gas.

(c.) *The protoxide and the hydrate are dissolved without effervescence*; the carbonate with extrication of carbonic acid gas.

* Thénard, Vol. I. p. 184.—Acc. Vol. II. p. 112.

† Hence sheet lead is used to line the oil of vitriol chambers, and the first concentration is performed in leaden boilers, although finished in glass or platinum.

‡ Found native at Lead Hills in Scotland, and at Paris Mountain in Anglesey, crystallized in quadrangular pyramids, in the latter case, and in the former in transparent tables. Found richly argentiferous at Monroe, Connecticut.

§ Produced in immense quantities in preparing the alum liquor, or acetate of alumina, for the calico printers; acetate of lead is mixed with alum. For various processes by which this sulphate may be turned to account, see Ann. de Chim. et de Phys. T. XX, p. 275, and Thénard, 5th Ed. Vol. III, p. 200. The following may be useful.

1. Sulphate of lead is mixed with 3 per cent. (trois centièmes,) of charcoal, and heated to redness: products, sulphurous acid gas, and oxide of lead.

2. Silica, by ignition, forms with this salt a glass of lead, which may be used in glazing, and forming crystal glass.

(d.) *Minium*, as already stated, is partly dissolved and partly peroxidized.

(e.) *In either case, a nitrate of lead is found in solution.*

(f.) *The concentrated acid leaves a dry mass, which is a sub-nitrate.*

PROPERTIES.

(a.) *Soluble in 8 parts of water; the solution is not decomposed by that fluid; taste sweetish and acid; by evaporation affords tetrahedral, or octahedral crystals.**

(b.) *On burning coals they decrepitate, but do not deflagrate. This salt is decomposed by heat,† and the oxide is precipitated by alkalies.*

(c.) *The solution of the nitrate is one of the best forms in which a soluble salt of this metal can be kept for use; it is best made by decomposing acetate of lead by carbonate of potassa: washing the residuum till it is tasteless, and then dissolving it in diluted nitric acid.*

(d.) *Composition*,—acid 1 equiv. 54

oxide of lead 1 “ 112

166 its equivalent.

There are several other varieties of nitric salts of lead. A sub-nitrate is formed by boiling together in water, equal parts of nitrate and protoxide; or 10 of nitrate with 7.8 of lead; pearly scales are the result.‡

3. (a.) *Muriatic acid*, even when hot, scarcely oxidizes lead.

(b.) *The muriate and chloride of lead were formerly confounded.*

(c.) *The muriate is formed by the action of muriatic acid upon the oxides of lead, restricting the statement to the part which is dissolved, this alone is regarded as true muriate, while the white precipitate is chloride.*

(d.) *The muriate is most easily formed, by mingling the solution of any soluble alkaline or earthy muriate with that of the nitrate or acetate of lead.*

(e.) *Soluble in dilute nitric acid; in 22 parts cold water, and in much less of boiling water, so that in cooling small needle prisms are deposited,§ and larger ones by slow evaporation.*

* Dr. Black asserts, (Vol. II, p. 608,) that they are triangular prisms, like those used for optical experiments. Mr. G. Chilton, of N. York, has large octahedra and tetrahedra, with all the modifications, formed by LeBlanc's method of increase.

† The nitrous or hypo-nitrous acid being obtained in this manner.—Vol. I. p. 452.

‡ For a notice of the nitrite—sub-nitrite, and hypo-nitrite, see Henry, 11th Ed. Vol. II, p. 128, and *Annales de Chimie*, Tome LXXXIII.

§ Muriate of silver is entirely insoluble even in boiling water, and is promptly tarnished by light, which forms an excellent distinction between it and muriate of lead: the muriate of lead may also be entirely separated from the muriate of silver, by boiling water, and it is soluble in acetic acid, which is not the fact with the sulphate of lead, and muriate of silver.

CHLORIDE.

(a.) *All the solid muriates of lead are now regarded as chlorides ; including the precipitate, the crystals and the translucent fused muriate, formerly called plumbum corneum, or horn lead.**

(b.) *Thirty grains of lead filings take fire in 60 cubic inches of warm chlorine gas, and burn with a white flame and scintillation, and produce chloride of lead.*

(c.) *Properties.*—*Volatile by a high heat, astringent and sweetish.*

(d.) *Composition.*—Chlorine 1 equiv. $36 + 1$ of lead, $104 = 140$, its equivalent. As muriate—acid $100 + 409.06$ protoxide, corresponding to metallic lead $380.06 +$ chlorine 129.—H.

(e.) *Chlorine gas is easily obtained by adding muriatic acid to red lead ; theory the same as in the case of black oxide of manganese ; the insoluble matter that remains is chloride of lead.*

If chlorine gas be passed through red lead diffused in water, chlorate of lead is formed,† and the brown oxide is precipitated by potash.

4. *Acetic acid‡ produces, 1. indirectly, a carbonate, 2. directly, acetates.*

1. *Carbonate.*

(a.) *The decomposition of vinegar, aided by the air, produces white lead, or ceruse, which is a carbonate. There are various modes of effecting the object in view, which is to bring the vapor of vinegar into contact with an extensive surface of lead : the following is an example.*

(b.) *Vinegar is put into a stone ware pot, or a box, and a little above its surface, on a ledge or frame, are set sheets of lead, of several feet long, and from $\frac{1}{4}$ to $\frac{1}{2}$ of an inch thick, and loosely coiled ; they are not rolled, but cast to aid the corrosion of the metal.*

(c.) *The vessel is set in a bed of tan and horse manure, and covered with a plate of lead, and the fermentation, evolving heat, raises the vinegar in vapor. In about two or three weeks or months, as the case may be, the surface of the sheet is incrustated with white lead, which is passed between rollers, or scrubbed with wire brushes ; to avoid injury to the workmen, this is now done under water. The sheet is then replaced, and corroded anew ; the car-*

* A muriate or chloride is formed by muriatic acid 1 and litharge three, or by the decomposition of common salt with water, by litharge ; caustic soda is evolved, which becomes carbonate and is removed, and the melted chloride is the patent yellow. Mr. G. Chilton informs me that red lead does not decompose salt, in the moist way, at any temperature, up to boiling, although the contrary is stated in most chemical books.

† Chenevix's memoir.

‡ As the acetic acid is known to every one, I prefer introducing here the important salts which it forms with oxide of lead, rather than to wait for the history of the acid under vegetable bodies.

bonic acid and oxygen are derived both from the air, and from the decomposition of the vinegar.

(d.) *In commerce, carbonate of lime, and sometimes sulphate of baryta, is mixed with white lead.* It used to be said, many years ago, that the laborers in white lead works seldom survive more than 3 years, dying miserably of the painter's colic, or of marasmus, or lingering with paralysis.*

(e.) *The manufacture is now much less injurious, especially since the dust is avoided.*

I have been informed, that white lead is manufactured by some persons in this country, by decomposing the acetate of lead by a carbonate of an alkali, and thus all danger is avoided.† There is still another mode of manufacturing white lead‡ which will be mentioned under the acetate.

(f.) *Composition.*—Carbonic acid 1 equiv. 22+1 equiv. protoxide of lead, 112=134 its equiv. : per cent. carbonic acid 16.5 oxide of lead 83.5.§

2. *Acetate of lead, or saccharum Saturni.*

(a.) *Formerly prepared, by dissolving pieces of lead in vinegar ;* but this is no longer done.

(b.) *The usual process is to dissolve white lead,|| or litharge, or other oxide of lead in vinegar ;* pyroligneous acid is now generally used ; the solution with acid in excess, is made in caldrons of lead, or tinned copper,¶ and after due concentration and slow cooling, it crystallizes.

(c.) *Crystals, long quadrilateral or six sided prisms, with dihedrall summits ;* sometimes delicate and sometimes large.

(d.) *Taste sweet** and astringent ;* soluble in 4 parts of water, either hot or cold ; more soluble with an excess of acid. It is efflorescent.

(e.) *Decomposed by most acids,* particularly the sulphuric and muriatic and their soluble salts ; and is very much used to form compounds by double exchange ; e. g. the acetate of alumina with alum, the acetate of zinc, with white vitriol, &c.

* Gregory's Econ. of Nat. Vol. II, p. 206.

† As a chemical experiment, it succeeds perfectly well, but the paint is said to be destitute of body.—G. C.

‡ White lead is also a beautiful native mineral ; but only the manufactured white lead is used as a paint, and not for white only, but for many other colors, of which, blended with other pigments, it forms the basis.

§ White lead is formed by the weather on sheet lead on the outside of buildings ; also in leaden inkstands, from the vinegar in the ink, and in water pipes and reservoirs of lead.

|| Taking that of course which has not been mixed with chalk.

¶ Thénard, Vol. III, p. 615.

** Hence the name Saccharum Saturni or sugar of Saturn or lead.

(f.) *Hydrogen gas revives the lead of this salt*, attracting the oxygen. A card, with an inscription of solution of acetate of lead becomes legible by contact with hydrogen, or better with sulphuretted hydrogen, which acts promptly and strikingly; in this manner it forms a sympathetic ink. White lead paint, as we often see, becomes discolored in various situations, from contact with such gases.

(g.) *Lead tree, by zinc*, or arbor Saturni. *Zinc precipitates lead from the acetate, and forms a beautiful ramose crystallization*; the zinc should be fresh cast or scraped and suspended from a stopper in a clean white bottle; it should stand undisturbed; the solution, in the proportion of 1 oz. of acetate of lead to 2 quarts of water; the tree will increase for several days; the first effect is chemical, a mere transfer of oxygen and acid, and formation of acetate of zinc, but afterwards it is a galvano-chemical phenomenon. The nitrate of lead answers equally well for this experiment. *This is a good method to obtain lead pure.*

(h.) *Acetate of lead is a virulent poison.**

TESTS.—Solutions of all sulphurets and hydro-sulphurets produce a dark cloud; the famous Wirtemberg test was 2 parts sulphuret of arsenic, 4 lime, and 12 water; liquid sulphuretted hydrogen is very efficient. It is said that the very minutest quantities of lead are not detected by sulphuretted preparations; in this case, probably, the lead would do no harm, but it may be precipitated by sulphuric acid or a soluble sulphate, and then reduced to the metallic state.

(i.) *Burns on a red hot iron*, the acid affords the combustible matter; distilled, it affords a volatile, fragrant inflammable fluid resembling alcohol and ether.

(j.) *Much used under the name of lead water*, externally against inflammation; as an astringent against hemorrhages; internally, although with caution.†

(k.) *Solution of acetate of lead is partially decomposed by the carbonic acid of the atmosphere*, but the precipitation is too slow to be readily perceived, even when carbonic acid gas is blown through it from the lungs; a little excess of acid is necessary to preserve the solution clear when it is long kept.

* Sour wine is said to have been formerly sweetened by sugar of lead, or by putting litharge into the barrel; in France, the old government interfered to prevent it. Cider, perry, &c. may contain lead from accident or design. In Devonshire, England, their cider presses were formerly made tight by white lead putty, and other preparations of white lead; hence the cider, which, in England is very acid, was unintentionally poisoned. Wine has been known to contain 40 grains of metallic lead in 50 gallons. Wines, (such as Burgundy,) that contain much Tartaric acid, precipitate lead, and therefore cannot be adulterated by it.

† 1 drachm with 5 oz. distilled water, is a strong solution, and the same with twice as much water, a weak one.

SUB-ACETATE OF LEAD.

(a.) *Boil litharge in vinegar, and it produces what was formerly called Goulard's extract, which is a sub-acetate of lead.*

(b.) *Neutral acetate of lead, 1 part, + 2 of pulverized litharge freed from carbonic acid by heat, boiled for 10 or 15 minutes with 20 or 25 parts of water, filtered and concentrated, affords crystals of sub-acetate, in plates opake and white.*

(c.) *Less sweet than the acetate, and less soluble in water, not altered in the air, and contains three times as much oxide.*

(d.) *This sub-acetate precipitates white lead in great abundance, when carbonic acid is brought into contact with it; common water contains carbonic acid enough to trouble it, and even distilled water, if it has been sometime exposed to the air.*

(e.) Thénard, many years since, pointed out this method of making white lead;* *the same acetate may be used always; for no sooner has the carbonate been precipitated, than the remaining acetate, by being boiled on more litharge, becomes again sub-acetate, and carbonate of lead may be again precipitated by carbonic acid as before, and so on.*

(f.) *The sub-acetate is very efficient in precipitating gum, tannin and most solutions of animal matter.*

(g.) *Composition of the acetates of lead.*—Neutral acetate—acid 1 equiv. 50, + 1 equiv. of oxide of lead 112, + 3 of water 27, = 189, its equiv.; per cent. acid 26.97, oxide 58.71, water 14.32.

Sub-acetate—acid, 1 equiv.	-	-	-	50
protoxide, 3 equiv.	-	-	-	336=386
per cent. acid,	-	-	13.23	
protoxide,	-	-	86.77=100.00	

There is also a compound of 1 equiv. of acid, 2 of base, and 10 of water, made by boiling crystals of acetate of lead with litharge.†

3. *Phosphoric acid.*—*Phosphate of lead.*

(a.) *This salt may be formed directly, but it is easiest done by mingling phosphate of soda with acetate or nitrate of lead, and the yellowish white phosphate precipitates.*

(b.) *If the acetate or nitrate of lead be mixed with urine, the phosphate of lead is abundantly precipitated, from the decomposition of the phosphates contained in that fluid, and this forms a good foundation for the manufacture of phosphorus, as the phosphate of lead is decomposed by ignition with charcoal.‡*

* That is, by causing carbonic acid gas to pass through the solution of sub-acetate, formed as in (b.). Two extensive manufactories, one in New York, the other in Brooklyn, have given this method a fair trial. They used pyroligneous acid for the solution, and forced carbonic acid from burning charcoal into it, but the pigment has neither the body nor the unctuousness of that made in the ordinary way. The method is now abandoned.—G. C.

† The first salt named under (g.) is the tris-acetate, and the second the di-acetate, of Dr. Thomson, First Prin. II, 373.

‡ Vol. I, p. 437.

(c.) *Composition*—acid, 1 equiv. 28, + 1 protoxide 112, = 140, its equiv. There is another salt, with 1 of acid and 2 of base, called by Dr. Thomson, a di-phosphate. Phosphate of lead exists native, in green and brown crystals, prisms of six sides.

4. *Chromic acid*.—*Chromate of lead*.

(a.) This beautiful salt is *found native*, in Siberia, in scarlet and crimson prisms.

(b.) *All that is used in the arts, is manufactured, by mingling chromate of potassa, (Vol. II, 149,) with acetate of lead; it falls as a superb yellow precipitate.*

(c.) *It has now supplanted the patent yellow, (fused sub-muriate of lead,) and in a good degree the orpiment or yellow sulphuret of arsenic, which was very injurious to the painters.**

(d.) *Composition*.—Acid, 1 equiv. 52, + 1 of protoxide 112, = 164, its equivalent.

There is also a di-chromate of lead, with 1 equiv. of acid and 2 of base, formed by boiling carbonate of lead with excess of chromate of lead; it is of a beautiful red.†

IX. ALKALIES have *little action on lead*, but if caustic and boiled on it, they corrode it, and promote its oxidation. They readily precipitate the oxides of this metal from their acid combinations, and if in excess, they redissolve the oxide.

X. EARTHY BODIES, as already stated, *by fusion, readily unite with the oxides of lead*, producing in different proportions and mixtures, the lead glaze for pottery, flint glass for optical instruments and elegant furniture, and pastes for imitations of the gems; used also in working the ores of the precious metals.

The oxide of lead increases the refracting and dispersing power of vitreous compositions, more than any substance, so that the pastes and glasses made with it, approach, in this respect, very nearly to the diamond; but they are soft and are soon scratched.‡

* Before the discovery of chromate of lead, orpiment was extensively used in painting the bodies of chariots, &c.

† Ann. Philos. N. S. XI, 303.

‡ Flint glass is rarely uniform in its composition; the great weight of the oxide makes it subside, and when the workman collects it on his pipe, it forms strata of different density and refracting power, which greatly disturb the formation of a fine image. By a large dose of minium, a paste is formed, which is scarcely inferior to the diamond in brilliancy and refracting power, and superior in the dispersive; with a very small addition of antimony, a paste is produced resembling the finest topaz.

Oxide of lead, is indispensable for *enamels*, as arsenic and tin alone, will not do; (*Black*;) but if there is too much lead or if it is imperfectly calcined, it imparts a yellow color.

It is much used in the glazing of earthen ware, both white and yellow, but it is liable to corrosion by acids. Vinegar readily attacks the common soft glazing on earthen ware, and obtains a noxious impregnation. Pickles should not be kept in such vessels. There are no vessels fit for this purpose but those of glass porcelain or true stone ware; those glazed with common salt, (the common gray ware) are safe.

XI. SALTS.

1. *In relation to lead, the action of the muriates is chiefly interesting.* The decomposition of common salt, by litharge, has been already mentioned; but, (a seeming paradox,) the *muriate of lead is decomposed by soda*, and again the *muriate of soda by oxide of lead*; and quantity has been supposed to compensate for feebleness of attraction. There is a double product of caustic of soda* and chloride of lead; which, after fusion, is patent yellow and pays the expense. About 7 parts of litharge are mixed with 1 part of the salt.

2. *Muriate of ammonia*, by trituration or by heat, *is decomposed by the oxides of lead*, with disengagement of ammoniacal gas.

3. *There is a decided action between red hot nitre and lead.* China tea chest lead, in cuttings, or small shot may be mixed with nitre and charcoal powder in an ignited crucible, or thrown upon burning charcoal, when there will be a brilliant combustion; but it is not a good experiment, as the fumes are very dangerous; if done at all, it should be under a good vent.

4. *Chlorate of potassa*, 3 parts, and *lead filings*, 1 part, *fulminate*, by percussion, and burn by contact of an ignited body.†

XII. *Iodine unites with lead*, by heat, or by mingling hydriodic acid, or hydriodate of potassa with acetate or nitrate of lead. *It is a beautiful yellow powder*, much resembling the chromate of lead.

Composition—1 equiv. of iodine 125, + 1 of lead 104, = 229, its equivalent.

XIII. ACTION OF OTHER METALS.—ALLOYS.

1. Protoxide of lead 100, + 60 carbonized cream of tartar, give, by heat, an alloy of lead and potassium; it is silvery and fragile, and becomes a pyrophorus, by adding 5 or 6 parts of lamp black to the mixture, from which it is formed.

2. *Arsenic unites with lead*, by fusion, and the alloy having one sixth of arsenic, is composed of plates, brittle and dark colored.‡

3. *Cobalt*, wrapped in sheet lead and covered with burning charcoal, contrary to former opinions, *unites with lead*, although with difficulty; the alloy is not interesting.

4. *Antimony with lead, by fusion, produces, when they are equal, a porous and brittle alloy*; with 3 or 4 lead, to 1 of antimony, the alloy is compact, malleable, and harder than lead; *this alloy forms printer's types*, and the great use of the antimony is to harden the lead—bismuth is sometimes added to give hardness and precision; also, copper, zinc, and tin, are occasionally used; copper, especially in

Glass, containing lead, is blackened when the sulphuretted preparations are kept in it; they soon line it with a semi-metallic film, like a tea chest; and flint glass is blackened by the flame of the blowpipe, owing to the reduction of the lead.

* Which becomes a carbonate by attracting carbonic acid from the air.

† Four. VI, 125.

‡ Thénard, I, 252.

the proportion of a few hundredths. With $\frac{1}{3}$ of antimony, the alloy is considerably harder than lead and very malleable; with $\frac{1}{2}$ of antimony, it is harder than lead, but in other respects perfectly similar—the sp. gr. is more than the mean.

5. *Zinc may be united with lead, by fusion*, especially if the melted lead is covered with suet, the zinc thrown in by pieces, and the alloy removed and cast, as soon as formed. It has different properties, according to the proportions of the ingredients, but, it is not particularly interesting.*

6. *Bismuth unites with lead, by fusion*, and increases its tenacity. An alloy of 3 parts of lead and 2 of bismuth is 10 times as coherent as lead alone. Sp. gr. greater than the mean. It is of a dark gray color and close grain, and is ductile unless the bismuth predominates.

7. *Tin and lead unite, by fusion*, in almost any proportions—the alloy has more hardness and more tenacity than tin—these qualities are at a maximum with 3 of tin and 1 of lead. This alloy is often contained in pewter, in which tin is always the principal metal; but tin may contain 33 or even 50 per cent. of lead without yielding it to vinegar; organ pipes are made of this alloy, and nails, which can be driven into oak, and do not rust in salt water, are made of 3 parts of tin, 2 of lead, and 1 of antimony.

Tin-foil usually contains some lead; 2 parts of lead to 1 or 2 of tin, form the *plumber's solder*.

The famous fusible metal of Sir Isaac Newton, is composed of 5 parts of bismuth, 3 of lead, and 2 of tin—8 bismuth, 5 lead, and 2 tin, are more fusible still; and 9 bismuth, 5 lead, and 3 tin, still more so:—*Dr. Hope*.

Sir I. Newton's metal is fusible below 212° , and a spoon made of it melts in the stream from a boiling tea urn.†

XIV. NATURAL HISTORY.—*Lead is presented, in nature, in many forms*. If native lead is found at all, it is very rare. Its proper ores are the sulphuret, the oxide and native salts.

The salts are beautiful and interesting objects in cabinets, but the *sulphuret*, called *galena*, is the only abundant ore, and the only one which is wrought for lead. Found massive or crystallized in cubes, octahedra, &c. often brilliantly foliated or granular like steel. The granular has been supposed to contain the most silver, for galena generally contains silver, and frequently enough to pay the cost of extraction, when the silver is the principal object. Galena, being used by potters for a glaze to their ware, is called potters' lead ore. It is abundant in the United States, and the Missouri mines are without a parallel for extent and richness; they alone can supply the world.

* See Fourcroy, Vol. VI, p. 106; Thomson, I, 264, and Aikin's Dict. IV, 29.

† These fusible alloys may be used with some advantage to take copies from medals, &c. and to form models of the ear and other anatomical resemblances.

XV. EXTRACTION.

1. *Assay.*—*Lead ore (the sulphuret) is assayed by roasting and fusing it in a crucible, with three parts of black flux ; more accurately, by solution in acids, precipitation by zinc or alkalies, and reduction as above.*

2. In the large way, the picked ore is roasted in a reverberatory, to expel sulphur ; it is agitated to bring it to the air ; when the lead begins to soften, the heat is lowered to give time for the sulphur to exhale ; charcoal is then added, the mixture is stirred, and the heat gradually increased ; lime is thrown in to solidify the scoræ, the lead is reduced, and runs out at proper apertures in the bottom of the furnace, into a convenient receptacle, lined with charcoal ; the scoræ are again heated more intensely, lime thrown in, and more lead obtained, but less pure.

3. *The proportion of silver is judged of by cupellation, which will be mentioned again under silver ; in a word, a small piece of metallic lead is heated under a muffle, upon a cup of bone ashes, until it is oxidized ; the oxide is absorbed by the porous vessel, and the silver remains a brilliant point.* In the humid way, the sulphuret may be dissolved in very dilute nitric acid, and precipitated by a solution of common salt, which will throw down both the muriate of lead and the muriate of silver ; the former may be dissolved out by boiling hot water, or by dilute nitric acid, and the latter obtained upon the filter and reduced by the blowpipe.*

4. *In the large way, the lead is placed either in a great cupel, made of bone ashes, or in a cavity in the hearth of the furnace, covered with ashes, or marl earth, and upon this bone ashes are placed ; it is done in a reverberatory furnace, whose hearth is made of such materials as to withstand, as far as possible, the action of the oxide of lead. The melted lead is heated and oxidized by the blast of air from large bellows, blowing obliquely over the metal, and thus also forcing the scum or oxide to one side as fast as it forms, where it is withdrawn.*

This oxide of lead, after additional treatment, is litharge,† and the silver remains brilliant, because it does not in this way combine with oxygen. The vaporized lead produces dreadful maladies, sometimes instant paralysis in the workmen, so that the arm that was extended cannot be withdrawn.

XVI. USES.—*These are well known, or have been chiefly mentioned already.* It may be added, that litharge, when used to dry

* The lead of commerce, treated in this way, commonly affords a portion of silver ; I have extracted it from the lining of the China tea chests.

† The oxide of lead thus formed, may be easily reduced to lead again by heating it in contact with charcoal. Previously to the operation for the extraction of the silver, the lead is itself extracted from its ore by the above simple process.

oil, probably operates by imparting oxygen to mucilage, and other principles. In war, it is preferred as a projectile, because it is so heavy and so cheap.

Although a virulent poison, its salts are administered internally, but with great caution in epilepsy, and as an astringent in hæmorrhages, &c.

Its principal medical use is, externally, against inflammation, as already mentioned under the acetate, which is the form commonly used, instead of the old extract of Goulard. Lead is the basis of many plasters and salves. Painters are affected by the colic, and various distressing maladies, arising perhaps more from oxide of lead than any other pigment. *Occasional substitution of other employments; great cleanliness, to avoid introducing any lead into the system, and great temperance, are perhaps their best preventatives; alcoholic remedies do more mischief than the lead.*

SEC. XXX.—IRON.*

I. HISTORY.—Its discovery is uncertain; subsequent, however, to that of gold, silver and copper; mentioned often by Moses and the early writers in the Bible. Tubal Cain wrought in brass and iron. Its use was not common among the ancient nations, and the perfection of its manufacture has been attained only in modern times.

The most useful and most abundant of all the metals; indispensable to the highest state of civilization. Except for medicine and science, it may be substituted for all other metals. Anciently called *Mars*; and its preparations *Martial*, a term that is still retained.

II. PROPERTIES.

(a.) *Color, bluish, or grayish white*; when polished, very brilliant.

(b.) *Taste styptic*; when rubbed, emits a peculiar smell; cuts or scratches all the other metals, and in the state of hardened steel, it impresses most natural bodies; it is the most elastic metal, especially in the condition of steel.

(c.) *Texture fibrous*, or in grains or small pointed plates; according to the heat or pressure it has suffered.

(d.) *Sp. gr.* 7.5 to 7.8. A cubic foot of forged iron weighs 545 pounds.†

(e.) *May be made magnetic*, either by the touch of a magnet, by electricity or galvanism, or by percussion; and by standing some time vertically, or at an angle of 70° ; the natural magnet is nearly a protoxide; artificial magnets may be made much more powerful than the loadstone; iron loses its magnetism more rapidly than steel.‡

(f.) *Imperfectly malleable in the cold; perfectly so when red hot*; its thinnest plates are much thicker than those of silver, gold, and copper, and even of lead or tin.

* Olim Ferrum and Mars.

† Chapt. Chem. p. 349.

‡ Nickel and Cobalt are magnetic.

(g.) *In ductility, it exceeds all metals.* Its wires may be drawn more slender than human hair.*

(h.) *It is more tenacious than any metal.* A wire of iron $\frac{1}{8}$ of an inch in diameter, supports 450 pounds avoird.; it is even said that one of $\frac{1}{8}$ of an inch sustained nearly 550 lbs.; and in another case that iron $\frac{1}{8}$ of an inch in diameter, only broke with 740 pounds; wire drawing increases the cohesion of iron, and different iron wires may vary in strength, as the metal is more or less pure.

(i.) *In relation to heat, it is an excellent conductor, and very dilatable by that power,* but less so than copper, gold, silver and lead.

(j.) *No other metal takes fire by collision with flint.*

(k.) *Readily softened by heat;* can be firmly joined by welding.†

(l.) *Pure iron is nearly infusible in a furnace,* unless in contact with the fuel. Melting point, 158° Wedg.; it has not been crystallized by art.

(m.) *Becomes hot, and even red hot, by percussion,* and brittle from the emergence of latent heat; it will recover its malleability by being heated again.

III: RELATION TO OXYGEN.—Combustibility.

(a.) *Attracts oxygen with energy, and when heated in air or oxygen, burns vividly.*

(b.) *This is seen in the shops of the smiths;* a bar of iron withdrawn from the fire at a white heat, emits on all sides brilliant sparks; it is called *brandishing*.‡

(c.) *The collision of flint and steel produces combustion;* the heat evolved ignites the detached coils or fragments of steel, and the oxygen burns them; § if struck off in pure oxygen gas, they are much more brilliant, and become oxide of iron.

(d.) *Iron filings burn beautifully in the flame of a candle, or of a common fire, or of burning paper, or in a fire fed by oxygen gas, as on burning charcoal.*

(e.) *A watch spring,|| or a bunch of fine wire, first ignited, burns in a bottle of oxygen gas;* in these cases, there is bright scintilla-

* Perukes have been made of them. Four. Vol. VI, p. 152.

† At nearly 1800° , Fahr. or 130° Wedg. In welding, some pounded sand-stone or clay is thrown into the fire; it acts as a flux; with the oxide of iron it melts into it a glass, and this glazing defends the metal from further oxidation, and it breaks and flies away when the two surfaces are violently brought together by the blow of a hammer. Bl. Vol. II, p. 468. Platinum and sodium are the only other metals that are weldable; the former at a high heat; the latter at a common temperature and with moderate pressure.

‡ Black, Vol. II, p. 459.

§ In a vacuum, or in any gas that does not support combustion, collision evolves heat, but without combustion, and the fragments are not oxidized.

|| Steel, on account of the carbon which it contains, burns much more brilliantly than iron, and cast iron, for the same reason, still more so, producing a splendid fire work.

tion, but iron gives no flame, because it is not volatile. In all these modes, iron is oxidized, and an entire bar of iron may thus be converted into black oxide.

(f.) *Water is decomposed by iron, even at common temperatures.**

(g.) *For the rapid decomposition of water in the state of steam, passing over ignited iron in a gun barrel, see the article Water, Vol. I. p. 209; for every grain in weight of the evolved hydrogen, the iron gains 8 grains.*

(h.) *From water boiled with iron filings in a retort, quite full of that fluid, hydrogen gas is evolved.*

(i.) *The rusting of iron, by which the largest masses, in time, crumble into dust, is due to the joint action of the oxygen of air and water, and carbonic acid from the atmosphere then unites with the oxide, as it does indeed with most metallic oxides.*

(j.) *It is no longer admitted that there is an indefinite course of oxidation in iron, as indicated by successive colors in polished iron, heated just below ignition, namely, iris, yellow, purple, violet, and blue, ending with red, at ignition.*

OXIDES.—Two oxides only are admitted.

All the methods mentioned above, except the last, produce a black oxide of iron,† which is still magnetic, and was, till recently, supposed to be the protoxide.

1. PROTOXIDE.—*The true protoxide is obtained by passing dry hydrogen‡ gas, at a low red heat, over peroxide of iron.§*

Properties.

(a.) *Color blue, imparts that color to vitreous bodies; attracted by the magnet, but less powerfully than iron.*

(b.) *Exposed fully to the air, it fires vividly and becomes peroxide.*

(c.) *Formed during the solution of iron in diluted sulphuric or in muriatic acid, hydrogen gas being evolved, and the proportion of oxygen combined with the iron being thus ascertained.*

(d.) *Precipitated as a white hydrate, by alkalies, as a white carbonate by alkaline carbonates, and as a white prussiate by prussiate of potassa; the two first precipitates become first green and then red, and the last green and then blue, by exposure to the air.—Turner.*

* As may be seen by placing iron filings beneath an inverted bell glass, filled with water, when the hydrogen gas will be slowly collected at the top. This is denied as to pure water, free from dissolved oxygen, and carbonic acid, in which it is said, immersed, iron remains bright; nor does bright iron rust in dry air.

† Formerly, when prepared by the first process, it was called *martial ethiops*. It is produced also by precipitating iron from its sulphuric solution, by potassa, and drying it quickly in close vessels.

‡ Iron filings, hydrogen and sulphuretted hydrogen, and many other substances, will reduce the peroxide of iron to the protoxide.

§ Stromeyer, Edinb. Jour. Sci. No. 10.

(e.) *Composition*.^{*}—Iron 28, one equiv. + one of oxygen 8, = 36, its equivalent.

2. DEUTOXIDE OR PEROXIDE.[†]

(a.) *Formed by dissolving and boiling iron in nitric or nitromuriatic acid*, precipitating by ammonia or other alkali, washing, drying and calcining in a low red heat.—*H*.

(b.) *Also, by heating and agitating iron filings or the oxides*, produced by either of the above modes, till they become a dark red powder,[‡] as in iron rust,[§] which contains also carbonic acid.

(c.) *Obtained by heating the red sulphate of iron, or by exposing the green sulphate to the air*, till it has become red, or by adding to it nitric acid or chlorine, and then precipitating the oxide by potassa.

(d.) *Found native in abundance*; the hæmatite ore is this oxide, (anhydrous;) and the brown hæmatite is the same, (hydrous;) the ochres are mixtures of the hydrated red oxide and clay.

(e.) *Properties*.—Color red or dark brown; not magnetic; its salts are red; the alkalies and alkaline carbonates precipitate it red, or it soon becomes red by exposure to the air.

(f.) *Composition*.—Iron one equiv. 28, + $1\frac{1}{2}$ of oxygen 12, = 40 its equivalent. The fraction disappears by doubling the numbers and supposing a lower proportion of oxygen than has yet been discovered, which would give two equivalents of oxygen in the protoxide, and three in the peroxide; but this has not been confirmed by experiment. According to the present view, most of the salts of iron are sesqui-salts.

(g.) What has been heretofore called the black oxide of iron is now regarded as a mixture of the protoxide and peroxide, varying in the proportions with the heat, the presence or absence of water, &c. It is said that the oxide formed on the outside of an ignited bar of iron contains more oxygen than that on the inside; the latter is constant in its composition, which is 3 of protoxide to 1 of peroxide, and the former is variable.

The native black oxide of iron, which is often crystallized in octahedra, is believed to have a similar composition; it is magnetic, and the native magnet belongs to this species.

IV. RELATION TO THE SIMPLE COMBUSTIBLES.

1. *Sulphur*.—There are two sulphurets of iron.

^{*} For the evidence in detail, and the results of different experimenters, see Henry, 11th Ed. Vol. II, p. 24.

[†] Iron, (excepting the metals of the fixed alkalies, &c.) yields only to manganese and perhaps to zinc in its attraction for oxygen. The oxides of iron are not reducible per se, but, by strong heating, in contact with carbonaceous substances, they return to the metallic state.

[‡] It was formerly called *saffron of Mars*, from its color.

[§] Varnish and paint protect iron from rusting; those paints are the best that become inspissated by drying.

1. *Proto-sulphuret.—Processes.*

(a.) A paste, made of equal parts of flowers of sulphur and iron filings, blackens and becomes an imperfect sulphuret, useful in eudiometry, (Vol. I, p. 193, 1. c.) as it attracts oxygen.*

(b.) *Heat equal† parts of iron filings and sulphur, with agitation, in a crucible or iron pot, till spontaneous ignition comes on*, as described, Vol. I, p. 342. The ignition may be exhibited in a glass tube or flask, by mixing sulphur 3 parts, and iron filings 1, heating them gradually, and finally one spot more than the rest.

(c.) *Rub a white-hot bar of iron with a roll of sulphur*; it will melt, and the drops are proto-sulphuret of iron.

(d.) *The proto-sulphate of iron is converted into proto-sulphuret, by ignition, in a crucible lined with charcoal.*

(e.) *Properties.—When formed by art, a dark brittle body, magnetic and easily yielding sulphuretted hydrogen gas by the action of diluted sulphuric or muriatic acid.†*

(f.) *It exists native,§ and is called magnetic pyrites.* It is of a bronze color; foliated and granular, and sometimes crystallized in six sided prisms; dissolves in acid, and gives the same gas as above.

(g.) *Composition*—one equiv. of iron 28, + one of sulphur 16, =44, its equivalent. The artificial sulphuret varies in composition, owing, as is supposed, to the mixture of metallic iron with it.

2. *Deuto- or bi- or per-sulphuret of iron.*

(a.) *Exists in vast abundance in nature, and is called iron pyrites.||* It is frequently crystallized, brilliant and beautiful, and being generally of a yellow color, more or less intense, it is often mistaken for gold.

* The filings and sulphur being fine and intimately mixed with a little water in a hot dish, will sometimes take fire, especially if this magma, in a larger surface, is smeared on some small twigs.—*Bl. II, 486.*

Fifty, or better one hundred pounds of the moistened materials, buried in the warm ground, or even placed in an iron pot, produce, in some hours, an eruption, called the *artificial volcano of Lemery*, the discoverer; and the fermentation of native pyrites was supposed to aid in producing natural volcanos, as they are known to kindle coal mines; a cause, however, altogether inadequate to the effect; see the article Volcanos, in The Outline of my Geological Lectures.

† Or 2 parts of iron filings and 1 of sulphur, correspond more nearly with the equivalents, but it is better to have some sulphur wasted than not to insure the saturation of the iron.

‡ See Vol. I, p. 342.

§ The native proto-sulphuret of iron or magnetic pyrites is abundant in this country, particularly at Strafford, Vermont, twelve miles west of Dartmouth College, where there is a great manufactory of sulphate of iron, (green vitriol,) from this native sulphuret; *Am. Jour.* Vol. III, p. 326. I have seen the mine and works; both are extensive; they are managed with skill, and present an object of great interest to the traveller.

|| Dr. Thomson mentions that in forming the common sulphuret in a covered crucible with a sudden heat, (and letting it cool, while covered,) pyrites, even crystallized, appear on the surface. I have repeatedly met with some thing similar, but have not seen any distinct crystals.

(b.) *Little affected by acids*; by heat in a close vessel, becomes proto-sulphuret, by giving up one equivalent of sulphur.

(c.) *Composition*.—Iron 1 equiv. 28, + sulphur two, 32 = 60, its equivalent.

2. Phosphorus.

(a.) *Phosphoric glass and iron filings*, each 2 parts, and charcoal 1 part; or phosphate of iron 4, with one of lampblack, *produce, by ignition, phosphuret of iron*.

(b.) *Properties*.—*Brilliant, fragile, fracture granular, color bluish gray*, scarcely magnetic* even in powder, fusible; with heat, corroded by nitric and nitro-muriatic acid.

(c.) *Of some importance, because it exists in some iron ores, and renders the metal obtained from them brittle*.† Cold short iron is malleable when hot; brittle when cold, owing to phosphuret of iron.

3. *Carbon readily unites with iron*;‡ this compound is *found native, in plumbago or black lead*; by art, it forms steel and the varieties of cast iron, which will be mentioned again at the end of this article.

V. *ACIDS act upon iron with much facility*; it is affected more or less by every acid or acidulous salt; most of its salts are easily formed, and some are very important.

1. Sulphuric acid.—1. Green or proto-sulphate.

(a.) *The strong acid, in the cold, scarcely acts*; with heat, it attacks iron; is in part decomposed; sulphurous acid gas is disengaged, and a sulphate obtained.§

(b.) *With acid, 1 part, water 6 or 8*, (Vol. I, p. 201–2,) and iron 1, the metal obtains oxygen from the water; hydrogen gas escapes, and *the acid forms a sulphate of protoxide of iron*, which, by filtration and evaporation, affords elegant green crystals.||

(c.) *Formed, in the large way, by converting the sulphuret into the sulphate of iron*;¶ this change either goes on spontaneously, the pyrites being laid in heaps, and sometimes acquiring so much heat, by their spontaneous action, as to burst into flame; more generally,

* Berzelius in Ann. de Chim. et de Phys. Tom. II, p. 233.

† The phosphate of iron, found particularly in bog iron ores, when ignited with charcoal, evolves phosphorus and thus forms phosphuret of iron. Bergman, the discoverer, at first imputed it to a supposed new metal which he called siderite.

‡ And, as has always been stated, *with no other metal*; but it is now believed to combine with nickel and perhaps with zinc; the latter is more probably a mixture. —Murray's Elem. 6th Ed. Vol. II, p. 228.

§ If the process be pushed to the utmost, sulphur is sublimed, and an uncrystallizable mass of sulphuric acid and oxide of iron remains.

|| Sometimes a black powder falls, which is carburet of iron, as the iron of commerce generally contains carbon.

¶ It would be foreign from the object, and inconsistent with the limits of a condensed elementary work, to enter into the details of this interesting manufacture. See Phil. Trans. Abridged, Vol. III, 461; Black's Lectures, II, 488; Dr. Watson's Essays; Thénard's Chem. 5th Ed. Vol. III, p. 189, and Am. Jour. Vol. III, p. 326. The

the change is accelerated by a slow combustion. Sulphate of alumina is often formed at the same time, and the sulphate of iron is separated, chiefly by crystallization.

(d.) *Properties.*—Color green; crystals transparent rhombic prisms; taste styptic and inky; reddens vegetable blues;* sp. gr. 1.83; soluble in 2 parts of water at 60°, and in three fourths of its weight at 212°; insoluble in alcohol; absorbs nitrous gas and becomes an eudiometrical agent; efflorescent in the air, becomes yellow, especially if moistened; by heat, melts and dries, losing .40 in weight; by a stronger heat is decomposed, and in the end, sulphuric acid charged with sulphurous acid gas comes over, often concrete, and was formerly called glacial oil† of vitriol. Vol. I, p. 307.

(e.) *A red powder remains, called colcothar of vitriol or crocus martis*; it is peroxide of iron;‡ it is much used in polishing metals; it is not magnetic, but by ignition gives out much oxygen gas and becomes magnetic.

(f.) *In commerce, called green vitriol, or copperas.*—It is decomposed by most of those salts whose bases form an insoluble compound with the sulphuric acid.§

(g.) *Alkalies precipitate a whitish green hydrate* from the solution.||

(h.) *Composition.*¶—Protoxide of iron 1 equiv. 36, acid 1 equiv. 40, water 7 equiv. 63, = 139, its equivalent.

(i.) *It attracts oxygen powerfully*, and is used to precipitate gold from its solutions.

(j.) *This salt of iron is of great utility** in the arts*, in dyeing, forming ink, prussian blue, colcothar, &c. and in many decompositions in which the sulphuric acid is needed, as of nitre and common salt, for their acids. In medicine, it is a tonic, astringent, &c.

magnetic pyrites are used with great success in this country, and appear to undergo the sulphatization, better than the common pyrites.

At Strafford, Vermont, the exhibition of the brilliant green crystals, as, (while draining,) they hang from the sticks on which they are crystallized, is very splendid; they fill large rooms with the pendent clusters. Pure sulphur is here sublimed from the decomposing pyrites, and forms elegant acicular crystals.

* Although it is neutral in composition, consisting of one equivalent of each of its constituent principles.

† The sulphuric acid was formerly procured by the distillation of this salt, and is still so in Germany. Four. VI, 260.

‡ Retaining, sometimes, a portion of acid.

§ As nitrate of silver, of lead, of baryta, &c.

|| Alcohol renders the powder of this salt white, as heat would do, and water restores the green color.

¶ It appears that this salt forms double salts with sulphate of potassa and sulphate of ammonia.—Turner.

** A mixture of equal parts of the dried sulphate and common salt, heated to a cherry red, for some time, then pulverized and agitated in water, deposits on decantation, a very fine, soft, scaly, violet brown peroxide of iron, extremely well adapted to sharpening razors.—Thénard.

2. Red or per-sulphate of iron.

(a.) *Formed by exposure of the green sulphate to the air, especially if in the state of a hot solution.*

(b.) *By boiling the green sulphate with nitric acid, or by passing chlorine gas through it, water giving oxygen to the metal, and hydrogen to the chlorine.*

(c.) *By adding 1 part of sulphuric acid to 1 of the green sulphate dissolved in water, with a small excess of nitric acid: it is then to be evaporated to dryness, and water dissolves from the residuum a per-sulphate, or sulphate of the peroxide.*

(d.) *Properties.*—Color yellowish red; uncrystallizable; taste sharp and styptic; deliquescent; more soluble in water than the green sulphate; when dry it is white and soluble in alcohol, which thus separates the red from the green sulphate; in the green vitriol of commerce, they are always mixed.*

(e.) *In the air a red precipitate falls, which is sub-sulphate of peroxide; in both the solutions of these salts there is always an excess of acid.*

(f.) *The earths and alkalies precipitate a red oxide, unchangeable in the air.†*

(g.) *The colors between the green and the red, are mixtures of these two.‡*

(h.) *The red sulphate is converted into the green, by iron, (in close vessels,) mercury, zinc and tin, and by sulphuretted hydrogen.§*

(i.) *With the red sulphate, astringent vegetables strike a black, and the alkaline prussiates a deep blue; with the green sulphate the first is almost null or only purple, the second white, but both deepen by exposure to the air.*

(j.) *Composition.—Peroxide of iron 1 equiv. 40, acid $1\frac{1}{2}$ equiv. 60, =100, its equivalent.*

In the modern language, this salt is, therefore, a sesqui-sulphate or a per-sesqui-sulphate.

Other sulphates are spoken of, but these are the only ones that are distinctly established, and with respect to them, I prefer to use, in general, the terms *green* and *red*, which are incapable of misapprehension.

2. *Sulphurous acid.*—The sulphite of iron appears to be of no importance.

* Found in the water after the crystallization of the green sulphate: deposited when green vitriol is dissolved in water, and the quantity of the precipitate becomes even a test (according to Scheele) of the proportion of air which the water contained.

† The precipitate from the green sulphate turns red in the air, because it absorbs more oxygen.

‡ For notices of the (so called) per-bi-sulphate and per-quadri-sulphate, see *Annals of Philos.* X. 102, XIII. 466 and 298 (H.) and *Thom. First Prin.* Vol. II. p. 328.

§ But the latter does not precipitate iron from its solutions, although they are thrown down by the hydro-sulphurets.

3. Nitric acid, forms a proto- and a per-nitrate.

1. Proto-nitrate.

(a.) Nitric acid, *sp. gr.* 1.16, acts slowly; there is no gas extricated for some time; solution dark olive brown; becomes pale by losing nitric oxide gas; *alkalies* give a green precipitate;* it is converted, by heat, into a per-nitrate.

(b.) With a very much diluted acid in the cold, the iron being in large pieces, added at intervals and away from the air, a green solution is obtained, holding ammonia.†

(c.) Uses of the nitrate of iron.—By boiling nitric acid upon iron, it is brought to the state of peroxide, so that in analysis, its proportion can be estimated. Etching on sword blades, knives, razors, &c. is done, by covering the instrument with varnish or resin, tracing the design with a pointed instrument, and then pouring nitric acid upon it, which will corrode the parts exposed to its action.‡ Used also by the dyer.

2. Per-nitrate.

(a.) If concentrated, nitric acid scarcely acts on iron; if diluted, it attacks it with much energy; in the state of *aqua fortis*,§ the action is rapid; heat is evolved, and in the air, clouds of nitrous acid gas rise, and the red oxide, probably with a portion of the blue, and retaining some nitric acid, chiefly subsides.

(b.) Uncrystallizable; color brown; by evaporation, deposits a red powder, not afterwards soluble in nitric acid; when concentrated, becomes gelatinous.||

4. Muriatic acid, diluted, easily dissolves iron; hydrogen gas rises, and a green solution and green crystals of proto-muriate are obtained.¶

1. Proto- or green muriate.

(a.) Properties.—More permanent in the air than any martial solution; absorbs nitric acid gas.

(b.) Very styptic, very soluble in water, and more so in hot than in cold; deliquescent.

(c.) Evaporated from a vessel with a small orifice, so as to exclude the air, it easily affords, by cooling, greenish white crystals, which are rhombic plates.

* Ammonia is prone to give a dark precipitate from the nitrate of iron, because, by its hydrogen, it detaches some oxygen.

† Which is extricated by adding lime or an alkali and rendered perceptible by the smell or by white fumes produced upon a feather dipped in muriatic acid. Proportions for this product, 2 drachms *aqua fortis*, † 4 water, as cold as possible; the solution being effected, add 3 drachms of lime—hold over a glass moistened on the interior with muriatic acid, and white clouds of muriate of ammonia will appear.

‡ For a process for browning iron by nitric acid, &c., see *Am. Jour.* Vol. IX, p. 168.

§ Equal weights of water and acid.

|| Iron was separated from earths by Bergman, by solution in nitric acid and evaporation with strong heat; the iron being thus rendered insoluble, the earthy nitrates can then be separated by water.

¶ Proportions, iron 1 oz., muriatic acid 6 oz., (equal in bulk to 5 1-4 water,) 2 1-2 oz. water. *Bl. II*, 469. Some carburet of iron is usually deposited during this solution.

(d.) *Composition* of the crystals—muriatic acid 1 equiv. 37, + 1 of protoxide of iron 36, + 3 of water 27, = 100, its equivalent.—*Thomson.*

(e.) *Alkalies precipitate a light green hydrate*; prussiate of potassa gives a white deposit.

2. *Per or red muriate.*

(a.) *Formed, by dissolving per-oxide of iron in muriatic acid,** with 3 or 4 parts of water.

(b.) By exposure of the solution of green muriate to the air, in the cold, the change is slow; with heat, it is more rapid.

(c.) *By adding nitric acid to the green muriate and boiling.* Chlorine produces a similar change.

(d.) *Properties.*—Solution of a deep brown; odor peculiar; taste astringent; reddens vegetable blues; *does not crystallize,†* but by evaporation, gives an orange colored mass.

(e.) *Deliquescent, and soluble in alcohol*; tinges animal substances yellow; with sulphuric acid, emits an odor of chlorine.

(f.) *Sulphuretted hydrogen turns it to green muriate*, by taking oxygen; it does not absorb nitric oxide gas.‡

(g.) *Partly volatilized; partly decomposed by heat*; some chlorine gas is produced, and the iron is partially metallized; (see the chlorides of iron.)§

(h.) *Muriatic acid readily dissolves the oxides of iron*;|| with several per-oxides, it evolves chlorine.

(i.) *Composition.*—Per-oxide of iron, 1 equiv. 40, + muriatic acid 1½ equiv. 55, = 95 its equivalent, (omitting a fraction.)

(j.) The common black oxide of iron, when dissolved in *muriatic acid*, gives a mixed proto- and per-muriate. (See Chlorides, p. 269.)

5. (a.) *Phosphoric acid acts slowly on iron* and dissolves it.

(b.) *The phosphate of iron is readily formed by double exchange, between solutions of phosphate of soda and green sulphate of iron*, in equal parts; the precipitate, which is bluish white, or of the color

* Concentrated muriatic acid, heated upon the red oxide of iron, evolves a little chlorine.—*Aikins.*

† Crystallize difficilement.—*Thénard.*

‡ The green muriate takes it with avidity, becoming dark brown, and as it then absorbs oxygen rapidly, it is employed in eudiometry.—*Davy.*

§ For more details, see Fourcroy, Thomson and Black.

|| Applications—to cleanse glass soiled by iron rust; to remove iron spots from linen; as the solutions of iron generally attract oxygen from the air, thus becoming less soluble, and are therefore precipitated and produce deep stains; they are generally removed by dilute warm muriatic acid, but if they prove obstinate, they may be touched by an alkaline hydro-sulphuret, which will bring them to the state of protoxide, when they will be soluble. Muriatic acid is much used in analysis, in dissolving the oxide of iron obtained from mineral waters, stones, &c.

of powdered slate, is washed and dried; if a per salt of iron is used, the precipitate will be white* (a per phosphate.)

(c.) *Properties*.—*Inspid; has the medical virtues of the carbonate of iron.*

(d.) *Found native both in the bog iron ores and in the blue iron earth, and in blue crystals, but these impure phosphates are never used in medicine.*

(e.) *Composition*.—Protoxide 1 equiv. acid 1 equiv. with variable proportions of water.

4. *Carbonic acid—carbonate of iron.*

(a.) *The solid or precipitated carbonate*, of pharmacy, is made by mingling 6 oz. of green sulphate of iron, in solution, with 6 of carbonate of soda; the precipitate may be washed with cold or tepid water till it comes off tasteless, and then dried and pulverized; when first precipitated it is greenish, but by the time it is prepared it is red.†

(b.) *Carbonic acid*, in aqueous solution, dissolves the protoxide of iron.

(c.) It aids the water in oxidizing the iron, and the protoxide unites with the acid to form a carbonate.

Chalybeate waters—artificial and native.

(d.) To form a mild and useful chalybeate water, suspend a little bag of clean iron filings, (free from brass and copper,) in a vessel of water, (e. g. Nooth's, Vol. I, p. 370,) through which carbonic acid gas is made to pass; in twelve hours it will be sufficiently strong.

(e.) Most native chalybeate waters contain protoxide of iron combined with carbonic acid; some with sulphuric.

(f.) If there is no more carbonic acid than is necessary to suspend the iron, the water has an inky taste; if the dissolved gas is abundant, the water will be brisk and sparkling.

(g.) *The most usual test§ is a nut gall*, bruised and suspended in the water, or a *tincture or infusion of galls*; if there is iron, there will be a purple cloud, beginning after some time, if the chalybeate is weak and gradually deepening in color.

* No precipitate will be obtained if there is excess of acid in the solution, because the phosphates are soluble in acids; hence it is better to employ a solution of the crystals of the green sulphate or of any soluble salt of iron; if we use the solution from iron obtained in the hydrogen processes, the precipitate fails because of the excess of acid.

† According to Mr. Phillips, it contains more peroxide than carbonate of iron; he recommends hot water on the score of economy, but cold water is better, on account of retaining the carbonic acid. An imperfect carbonate was formerly made, by sprinkling iron filings with water, which caused them to rust and thus to absorb carbonic acid from the air. The precipitated carbonate is an excellent chalybeate remedy, and is given in doses of five grains and more. It is best kept in lumps and then the outside only is red.

§ The succinate of ammonia is an excellent test for iron; see succinic acid, under amber.

April 7, 1850,

Prof: Stark's Ink, (of
Edinburgh)

Rt. Nut galls ——— $\frac{3}{4}$ lb
Sulphate of indigo (pure) $\frac{3}{4}$ viny
sulphate of iron ——— $\frac{3}{4}$ viny
Gum arabic — $\frac{3}{4}$ viny
Cloves ——— $\frac{3}{4}$ lb
Water ——— gal.

J.D.

The water should be a gallon
and a half, boiled to one gal.
Let the Gum arabic be

only ~~3 lb~~ $\frac{3}{4}$ lb

Made one gallon, as above,

Feb 7, 1852.
This is the above ink
February, 14, 1852.

(h.) The carbonated *chalybeate waters*, by standing, often become covered by an iridescent film of precipitated per-oxide.

(i.) *Prussiate of potassa* (ferro-prussiate) precipitates the iron light green, becoming blue by standing.

(j.) If the iron is suspended by carbonic acid, the latter will be expelled by boiling, and the oxide of iron will give a red* hue to the water; air pump exhaustion also removes the gas and allows the iron to precipitate.

(k.) If the iron is suspended by the carbonic acid only, it will no longer, after boiling and filtration, answer to the tests; but if it was suspended by a fixed acid, (sulphuric or muriatic) the tests will give more decisive indications after boiling than before.

(l.) The iron may be suspended both by a fixed and a volatile acid; in that case it will deposit red oxide of iron by boiling, and it will continue to answer to the tests for iron.†

5. *The vegetable acids.—Ink.—Black dye.*—It would be premature now to treat of the relation of the vegetable acids to iron, and they are mentioned here only for the sake of introducing one, namely,

(A.) *The gallic acid, which acts an important part in the formation of ink and of the black dye.*

(a.) The gallic acid, (so called from the gall nut, which contains it,) is used, as it exists in the astringent vegetables, combined with tannin and other principles.

(b.) *Ink powder is a mixture of the sulphate of iron, powdered nut galls and gum arabic*, and to form good writing ink, nothing more is necessary; these substances are inert as long as dry, but, when solution takes place they act on each other,‡ and strike the black color.

* Hence, in the channels where chalybeate waters flow off, there is a deposit of iron rust; also in the baths especially of hot water, and even in the drinking vessels.

† The natural chalybeates are very numerous, and nothing is easier than to detect them, by the indications named in the text and by their blackening tea, and generally the astringent infusions. Their utility, especially in many forms of dyspepsia and consequent debility, and of cutaneous affections, is undoubted, and they produce valuable effects, even when the portion of iron is very small and when there is no more carbonic acid gas (for this is generally the suspending agent) than is merely necessary to keep the iron in solution. If there is more (as at Ballston and Saratoga) these waters are then rendered still more grateful and salutary. They can be perfectly imitated by art.

‡ Among the numerous recipes for forming ink, the following has been found to be very good.

Powdered Aleppo galls,	- - - - -	8 oz.
Logwood, in thin chips,	- - - - -	4
Sulphate of iron, (copperas,)	- - - - -	4
Powdered gum arabic,	- - - - -	8
Sulphate of copper, (blue vitriol,)	- - - - -	1
Sugar candy,	- - - - -	1=21 oz.

Boil the galls and logwood in 12 lbs. of water, till the liquid is half evaporated; strain it and add the other ingredients; agitate it till the whole is dissolved, especially the gum; let it subside for 24 hours and decant the ink into bottles. In this recipe, the galls and the logwood afford the gallic acid and tannin; the copperas, the

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(c.) *Ink is liable to fade, from the decomposition of the vegetable matter*; writing is injured or destroyed in damp situations;* this is to a degree counteracted by powdered cloves or corrosive sublimate; alcohol would be still more effectual, but it makes the ink spread, and it soon evaporates.

(d.) In a solution of a salt of iron, when there is an excess of acid, the precipitate does not appear on adding infusion of galls.

(e.) *Alkalies decompose common ink*, and precipitate the color, the *tanno-gallate of iron*, (for such is ink,) and more alkali redissolves it; hence, after ink is dissolved by acids,† alkalies will restore the color.

(f.) *Chlorine destroys‡ the color of ink*, by decomposing the vegetable matter, while muriatic acid is formed and dissolves the iron.

(g.) *An ink, not liable to decomposition or to destruction by any agents that will not also destroy the substratum, is much to be desired*, since so many important interests depend upon written records. Carbon must evidently be the basis of such an ink,§ and accordingly the addition of Indian to common ink, renders the latter more durable.—(A. A. H.)

oxide of iron; the gum arabic and sugar serve to keep the precipitate suspended in the fluid and to give the ink lustre, covering it, as with varnish. Sugar, added to ink, enables us to copy a writing, by laying a sheet of thin unsized paper, damped with a sponge, on the written paper, and passing over it a warm flat iron. (Ure's Dict.) The blue vitriol is not indispensable, but improves the color. It however precipitates copper on the knife, if the pen is not wiped quite dry, and the acid corrodes the edge. Only the peroxide of iron forms a good ink; hence the reason why pale ink becomes deeper colored by exposure to the air. For other recipes and for various information, see Lewis' *Commercio Philosophico Technicum*, Black, II. 481, Tilloch's *Phil. Mag.* 1799, and Thénard, 6th ed. Vol. IV, p. 254.

* The color is restored, if the faded letters be retouched with an infusion of galls; and prussiate of potassa, followed by dilute muriatic acid, makes the writing blue.

† Ink stains are removed from linen or cotton by acids.

‡ As is commonly said, beyond the power of restoration; but it is asserted that the vapor of sulphuret of ammonia, will make the writing visible again, and, that prussiate of potassa, will do the same.—*Ure's Dict.* 526.

§ Dr. Lewis, by mingling fine lamp black with writing ink, made it much blacker; it was not injured by the weather, and it flowed freely from the pen. An ink not liable to be affected by chemical agents, is made from 25 grs. of copal dissolved with gentle heat, in 200 of oil of lavender, 2½ grs. lamp black and ¼ a gr. of indigo being added; or 120 grs. of oil of lavender, 17 of copal and 60 of vermilion, diluted to a proper degree with oil of lavender or of turpentine.—*Ure.*

Asphaltum, dissolved in about 4 parts of spirits of turpentine, with a little fine lamp black or black lead, will, it is said, form an ink for linen, &c. indelible by bleaching and other chemical processes.

The ancients wrote with levigated charcoal, one of the most indestructible of all substances; and accordingly, the writings found in Herculaneum, are still a perfect black. But, they could be easily erased, because, the color was only superficial, whereas our inks, penetrate into the very texture of the paper.—*Black.*

Printers' ink is a black paint, composed of lamp black, with sometimes a little indigo, and linseed or nut oil, inspissated by boiling, and modified by various additions; it adheres readily to damp paper, and does not penetrate or run. Carbon being its basis, it is not decomposed by chlorine. India ink, is only lamp black thickened by size or glue, and made into cakes with the unimportant addition of perfumes, &c.

Red ink for the printers, is colored by vermilion. Colored writing inks are made by suspending the different pigments in gum water; thus Prussian blue

(h.) *The black dye, for woollen, silk, cotton, leather, &c. depends on the same principles as writing ink.**

6. *Prussic or hydro-cyanic acid.*

This subject is mentioned here on account of the relation which it sustains to iron, in the remarkable compound called prussian blue. The observations in Vol. I. p. 417, will be sufficient to render its introduction here intelligible, and I shall now omit, as far as possible, all theoretical views respecting the prussic compounds, until the subject is finally disposed of, under animal substances. I shall use the old† nomenclature, as far as it involves no error, for in the unsettled state of opinion, on some parts of this complicated and difficult topic, a new nomenclature, adapted to particular theoretical views, is liable to convey erroneous impressions, as well as to be set aside by new discoveries, and that now in use is often both cumbrous, from the length of the appellations and repulsive from their want of euphony.

Prussiate of iron—prussian blue—ferro-cyanate of iron.

(a.) *Discovery*, 1704,† (Thénard,) by Diesbach, a manufacturer of colors, and by Dippel, a pharmaceuist, at Berlin, the substance having been obtained by the following process, which was accidental.

(b.) *Process*.—Four parts of fixed alkali and four of dried blood,§ are moderately ignited in a covered crucible; a solution, made in ten or fifteen times as much hot water, contains prussiate of alkali;|| the prussic acid, being formed by the union of the carbon, hydrogen and nitrogen of the blood, and although volatile, being detained by its affinity for the alkali.

(c.) *This solution is mixed with one containing 8 parts of alum and two of sulphate of iron*; there is an effervescence of carbonic acid and sulphuretted hydrogen gases; the prussiate of iron falls

gives blue ink; gamboge yellow ink, &c. Most of the common water colors, diffused in gum water, will make inks sufficiently good.

For red ink for writing.—Boil 2 oz. Brazil wood in 1 pint of water, for half an hour, adding sufficient gum and about half the quantity of alum; or steep 4 oz. of Brazil wood in vinegar for two or three days, and boil it for an hour—filter while hot, warm it again and add half an oz. of gum arabic and the same quantity of white sugar.

* Sulphate of iron is mixed with some of the astringent vegetable infusions. Log-wood and iron rust, dissolved in elder juice, in sour milk, or in the pyroligneous acid, are among the materials commonly used. It is important that the iron should be in the state of peroxide, and I have often advised the dyers of hats, &c. to bruise their green coppers, spread it out on a large surface, in the open air, and sprinkle it with water till it turns red; it is then found to strike a good black immediately. In the blackening of leather, no other addition than the sulphate of iron is necessary, as the gallic acid and the tannin have been previously transferred to the skin by steeping it in the astringent infusion of bark.

† Giving, however, the new terms, either in note or parenthesis.

‡ Usually stated 1710.

§ Horn shavings or any other fixed animal substance will answer.

|| With carbonate, hydro-sulphuret and muriate of the alkali.

down; the alum, by its excess of acid, neutralizes the superfluous alkali, and affords its alumina to the coloring matter, to dilute the color, otherwise of too intense a blue—almost black.

(d.) *Some muriatic acid is also added* to the washed precipitate, to dissolve any superfluous oxide of iron, and it immediately changes the color from a dingy green to a beautiful blue, which however is not perfect until it has been washed, once in twelve hours, with abundant water for twenty or twenty five days.*—Thénard.

(e.) *Properties.*—*Neutral, insipid, inodorous, deep blue*; a very strong pigment, and bearing large dilution with other colors; insoluble in water and alcohol, and in acids, unless hot and concentrated; strong muriatic acid, aided by heat, separates some of the prussic acid;† when made very dry it attracts moisture.

(f.) *Above 307° Fahr. it catches fire* and burns like tinder, leaving more than half its weight of oxide of iron, (54 to 60 per cent.)

(g.) *Decomposed by heated alkalies* and alkaline earths, forming prussiates of those substances and depositing red oxide of iron, still retaining some prussic acid; potassa is generally used for this decomposition, and it has been proposed to judge of the quality of the prussian blue by the intensity of the shade of color in the precipitate.

(h.) *With a solution of a pure proto salt of iron, the prussiate of potassa throws down a white precipitate*, which remains white, or acquires but a slight green color if kept away from the air; if exposed, however, and especially if agitated or if mingled with an acid, it instantly becomes blue.

(i.) *With a per salt of iron, the precipitate is intensely blue from the first*, but on drying it becomes almost black; hence Dr. Thomson supposes that prussian blue does not contain a peroxide, but rather the oxide of Gay-Lussac, intermediate between the prot- and peroxide, and containing 1 of protoxide and 2 of peroxide.‡

(j.) *The base of prussian blue is disoxygenized by sulphuretted hydrogen, or iron filings or tin*; it then becomes white or pale green, and re-acquires the blue color by recovering the oxygen.

(k.) It is supposed by some, that there are several compounds of the prussic acid with the oxides of iron; three with the peroxide and one with the protoxide.§

* The process described in the text will always afford prussian blue, but, as is said, (Aitkins' Dictionary, II, 252,) not always in profitable quantity. Probably there are facts known to the manufacturers of which scientific chemists are ignorant and which may be essential to make the product at once abundant and beautiful. The prussian blue of commerce contains much alumina and a little hydro-sulphuret of iron, which colors it brown.

† Robiquet.

‡ From the fact that prussian blue is always prepared from the green sulphate, it appears probable that the two known oxides of iron may both be present, and that the actual color of the pigment depends upon this mixture and that of the alumina.

§ But Dr. Turner says—In every good specimen of Prussian blue which I have examined, the ferro-cyanic acid was in combination with the peroxide of iron only.

(l.) Prussiate of iron, decomposed by heat, affords carbonate and prussiate of ammonia, carbonic acid and other gases, and leaves iron nearly reduced; also, if ammoniacal gas is passed through ignited charcoal, prussic acid is formed.

(m.) *Uses*.—A splendid paint for the inside of houses, for paper hangings, a basis for blue ink, and a dye for silk and wool. In chemistry, it is the *material* for all the prussic preparations; used sometimes in medicine for the effects of both the iron and the prussic acid.

VI. CHLORIDES.—These are *intimately connected with the muriates*; both oxides of iron, when combined with muriatic acid in the fluid state, are muriates; but in the solid state, and deprived of water of crystallization, they are supposed to be chlorides, of which there are two. (See the muriates of iron, p. 263.)

1. Proto-chloride.

(a.) *Formed*, by evaporating and *nearly igniting the green muriate*, away from the air, when a brittle lamellated mass will be obtained.—(H.)

(b.) *By subliming*, in a stone retort, *the green muriate* dried (as in a); water is evolved, and the proto-chloride is formed as a sublimate, in small white plates.

(c.) *By passing chlorine gas through an ignited gun barrel, containing iron turnings* and furnished with an *allongé** to receive the chloride, which sublimes and collects just out of the furnace.

(d.) *Composition*—(by theory,) iron 1 equiv. 28, + chlorine 1 equiv. 36=64 its equiv.—(H.)

2. Deuto-chloride or per-chloride.

(a.) *Formed by burning ignited iron wire, or an iron spiral*, in chlorine gas, which produces a substance “of a bright yellowish brown color,” with much lustre.

(b.) *As in (c.) (proto-chloride)*, only using an excess of chlorine.†

(c.) *Composition*—(by theory,) iron 1 equiv. 28, + chlorine 1½ equiv. 54=82 its equiv.

The chlorides of iron, when re-dissolved in water are muriates; water, as in other cases, yields its oxygen to the iron, and its hydrogen to the chlorine.

VII. *The alkalies have little action on iron*; perhaps they favor its oxidation. Alkalies cause the red oxide of iron to become black, as if by the loss of a portion of its oxygen.

VIII. *Earths are frequently found naturally united with oxide of iron*, which gives color to most colored minerals. By fusion with the oxides of iron, earthy substances become red, brown, blue, green, &c. as may be seen in glass, enamels and porcelain.‡

* An adopter.

† Thénard.

‡ Mr. Wedgwood used to say that a great part of the colors used on porcelain might be obtained from iron. Oxide of iron colors bricks and tiles red, and gives them and most clays a disposition to vitrify; hence the superficial vitrification so often observed on bricks: oxide of iron also communicates hardness to them.

IX. ACTION OF SALTS.

1. *The sulphates*, by ignition with iron, become sulphurets.
2. *Nitre*, 2 or 3 parts, with 1 of iron filings, projected into a red hot crucible, produces a brilliant combustion, and oxide of iron remains mixed with the alkali; iron filings are used in artificial fire works.
3. *Chlorate of potassa*, 2 parts, and iron filings 1, detonate by percussion and ignition.
4. *Common salt* is slowly decomposed by iron.
5. *Muriate of ammonia* is decomposed by iron and its oxides, especially if heated and moistened; ammoniacal gas and hydrogen gas are evolved, and muriate of ammonia with a portion of gas, and muriate of iron sublime.*

X. IODINE.—The iodide of iron is *formed by heating iron* filings, in a glass tube *with excess of iodine*. It is brown, fusible at a red heat, styptic; dissolved in water becomes a hydriodate of a clear green.—*Thénard*. More economically, by heating an excess of iron filings, with iodine and water in a flask, evaporating the clear liquor and heating the salt.—(A. A. H.)

XI. ALLOYS.

1. With *nickel* it combines with facility, and it is difficult to free this metal from iron; a natural alloy of this kind exists in the iron of meteors.
2. *Manganese* has a strong affinity for iron.
3. *Arsenic* by fusion, forms with iron a white, brittle, and crystallizable alloy; not magnetic; found native in arsenical pyrites and arsenical iron; gives the arsenical fumes and odor by heat and percussion; iron can combine with more than its own weight of arsenic.
4. *Cobalt* is with difficulty freed from iron, with which it is almost always combined; the alloy is hard and difficult to break.
5. *Antimony* is alloyed by fusion with iron; the compound is hard and brittle, and has a specific gravity less than the mean. It can be obtained also by heating 2 parts of sulphuret of antimony, and 1 of iron. Antimony has more power than most other metals to diminish the magnetism of iron. With 1 of antimony, and 2 of iron, it fires with a file.
6. *Zinc* combines with iron only with great difficulty, but it may be used instead of tin to cover iron plates.
7. *Bismuth* combines with iron with difficulty, and scarcely blunts the magnetic virtue of iron.

* The martial flowers are made by heating iron or oxide of iron and muriate of ammonia, in such proportions, that only one half of the muriate shall be decomposed; the heat is ultimately raised so that the undecomposed muriate rises in a sublimate and carries with it some of the iron, from which it receives a yellowish tinge; it is better to employ an oxide of iron in this process. It used to be sold in the shops under the very improper name of *Ens Veneris*.

8. *Tin forms the most useful alloy with iron*, giving the common tin plate, which is made by immersion of a bright iron plate in a bath of melted tin.*

XII. NATURAL HISTORY.

Iron is diffused every where.—Its ores are numerous and they exist in greater quantities than those of any metal or of all other metals. The native iron of mines is an object of much curiosity and that of meteors is still more interesting from its mysterious origin, and from its being invariably alloyed with nickel while the latter metal exists in no iron ore. In this work there is no occasion to mention any of the ores of iron except the oxides,† as they alone are wrought for the purposes of society. Among the other ores some are useful for other purposes, as the sulphurets for yielding copperas and sulphur; the arsenical for arsenic; the chromiferous for chrome, &c. but the oxides alone yield cast and bar iron, and the materials for steel.

The principal iron oxides that are wrought, are the magnetic iron to which belongs the load stone; the specular ore; the hæmatites, red, brown and black; the sparry ore; the argillaceous ores and the bog ores; none of these are materially magnetic except the first,

* The best tin plate, is manufactured in Britain, particularly at Caermarthen, in South Wales. Tin plate holds a place intermediate between an alloy and a coating. When the tinning has been two or three times repeated, the whole plate is more or less alloyed or soaked with the tin, so as to appear white, quite through where it is cut. The finest kind of tin plate, has a lustre and whiteness, scarcely inferior to silver, and the peculiar superiority of the English tin plate, appears to consist in the perfect smoothness of the iron, and the uniform application of the tin. At Caermarthen, the greatest care is taken to procure iron of great purity and malleability, and to make the plates perfectly smooth by passing them between successive sets of rolling cylinders of steel, case hardened, and capable of being adjusted to different distances; the plates are clipped at the edges to make them smooth, and all that are not perfectly even are rejected. They are then steeped in a weak acid liquor, and when taken out are thoroughly scoured with bran so as to become quite bright and polished; otherwise the tin will not adhere. This acid is often produced from the fermentation of rye flour and water, sometimes from fermented verjuice. In Bohemia three different stages of this acid liquor are used, and the iron plates lie as many days and nights immersed in it; they are then washed, scoured with sand and water, and to prevent rusting, kept under water till used. The tin is kept melted by a moderate charcoal fire in deep rectangular crucibles; it must not be too hot which would cause the plate to come out yellow; the oxidizement of the tin is prevented by placing grease, made from linseed oil and suet, on the top of the tin, and renewing it as it evaporates; it produces a very offensive odor. Just before dipping, some water is thrown on the melted suet which causes a violent agitation, and makes the surface quite bright. The iron plates are taken up *cornerwise* by forceps or pincers and dipped in vertically (on the continent the plates are wet when immersed,) and come out covered with tin, they are set up to drip, and this produces little knobs at the bottom which are taken off by a second, but partial immersion. Single plate tin is dipped *three* times, and double, *six* times. Lastly the plates are sorted, and cleaned with a rag and saw dust or bran. 19 1-2 lbs. of tin are taken up by three hundred plates of 12 by 9 inches. On the continent from 1-80 to 1-120 of copper is added to the tin to make it flow more easily; too much copper yellows it.—*Aikin's Dict.* I. 627.

† I include the spathic iron in this general designation.

but they all become so by being heated red hot, upon burning charcoal, especially with the addition of animal fat.

XIII. PROCESSES OF ART.

The full detail of the processes of art upon iron would require a separate work: nothing more is intended in the following brief sketch than to indicate the principle of the operations, so far that it may contribute to the enlargement of the student's knowledge.

1. *The Assay.*—The iron, previously roasted or not according to its nature, is intensely ignited in a crucible in a furnace, mixed with $\frac{1}{12}$ of powdered charcoal and some flux, as green bottle glass, lime, chalk or other proper additions; for 8 parts of magnetic iron sand, take 8 parts of fine bottle glass, 6 of limestone or chalk, and 1 of charcoal, and after an hour or more a button of metallic iron is found, whose weight compared with that of the ore furnishes the means of judging. For an exact result, an analysis by chemical reagents is necessary, but this is important to science rather than to the arts.

2. *The reduction on a large scale.*—This is only an extension of the assay by the furnace. In general the ores are first roasted in fragments of convenient size, with charcoal or other fuel, either laid in heaps on the ground or in peculiar furnaces, the object being to expel arsenic, sulphur and other volatile principles.

Cast Iron.—The roasted ore is now heated in a blast furnace,* along with charcoal or coke and limestone or clay according to the nature of the ore; the carbon, by its attraction for the oxygen of the ore, flies away with it in the form of carbonic acid gas, and carbonic oxide, and the limestone or clay, by fluxing the proper impurities, forms a slag with some of the oxide of iron; the slag is an opaque glass, variously and often beautifully colored; this floats and is withdrawn from the surface of the melted metal.

The latter which is destined to form pig or cast iron, is composed of iron rendered fusible by chemical union with carbon, and it often contains also phosphorus, chrome, manganese and sometimes probably titanium, silicium, aluminium, calcium, magnesium, and potassium.

This melted iron is now withdrawn and cast either into pigs in the sand or in moulds to form hollow ware. The cast iron is either white, which is hard and brittle and cannot be wrought; or gray which can be turned and bored, and is used for cannon; or black,

* The furnaces are of every height from fifteen to sixty five feet, and are constructed of the most refractory stones and bricks. They expand so much with the heat that they are very liable to crack, and are therefore often banded with iron. With a view of resisting the effect of expansion, a rock has, in one instance, been excavated almost fifty feet deep and lined with fire bricks; but on letting on the blast, the rock opened four or six inches from top to bottom.—Gray.

which is more brittle and fusible than either of the preceding varieties.*

3. *Bar Iron*.—Cast iron is rendered malleable by renewed fusion, and by agitation and pressure. In some cases,† the reduction from the ore is performed on the hearth of the finery furnace, as it is called, and the crude iron thus formed is, without being withdrawn, brought to a condition in which it can be converted into bar iron. The operation is substantially the same, whether it is done in this manner or by melting down the pig iron previously obtained from the blast furnace. In either case, the melted mass bedded in and covered by charcoal, is urged by the blast of bellows, and it is at the same time agitated by iron instruments; thus the excess of carbon is burned off, and the scoræ, consisting of the impurities that have been mentioned, are brought to the surface and blown or raked aside; the iron, the longer it is heated and agitated, grows less and less fusible, till it becomes pasty and tenacious, although still in full ignition; as soon as it will hold together, it is turned out of the fire, and the scoræ are knocked off with hammers: it is then again heated and when it has become so tenacious that it will bear to be moved from the hearth, it is withdrawn from the fire by great pincers or tongs, suspended by a chain from a swinging beam or crane; it is thus brought to an anvil and there subjected to the strokes of the heavy trip hammer, by which the scoræ and slag are pressed out and fall, in ignited semi-fluid masses; the iron, thus growing more tenacious, is returned to the fire and again to the hammer, and so on alternately, until it is fit to be forged into bars, or round iron, or to be flattened by the rolling cylinders, into sheet iron. The cylinders are sometimes employed to press out the scoræ and to aid in the reduction to the state of bar iron.‡

It is thought that bar iron often contains potassium, derived from the charcoal, and it is suggested that its better quality, when reduced by charcoal rather than coak, may be owing to this fact: according to Berzelius the most ductile iron may contain silicium.§

A substance resembling plumbago is not unfrequently found on the surface of cast and even of wrought iron, and adhering to the ladles in which melted iron is dipped out for casting.

4. *Steel*.—From some ores of iron, and particularly the spathic ore, by particular processes, steel is prepared, merely by converting the crude or cast iron into bar iron; it is called, for this reason, natural

* The same iron which if cast in sand, is soft enough to be turned in the lathe, with ease, is rendered almost too hard for that purpose, by being cast in thick iron moulds; this obviously depends upon the different rapidity of cooling in the two cases.

† As in the smaller establishments at Salisbury and Canaan, Conn.

‡ There is variety in these processes in different countries, but I describe those which I have seen practiced either in Connecticut, New York, or New Hampshire.

§ Ann de Chim. 78, p. 288.

steel and is used for coarse purposes.* But the usual method of making steel is by cementation,† which consists, in igniting bar iron in contact with powdered charcoal contained in earthen crucibles or boxes, the whole being placed in a proper furnace; blisters, arising from the extrication of gas, appear on the surface, and thence it is called blistered steel. The change appears to arise mainly from the absorption of a small portion of carbon. The quality of the steel is much improved by drawing it out, again and again, by the tilt hammer, when it is called tilted steel; it is then cut up with shears and called shear steel; and at last, the bars are doubled over, and made into small packets and drawn out again.

(a.) *Cast Steel*.—The best of the common steel is broken up, mixed with pounded glass and melted in crucibles in a powerful wind furnace and afterwards drawn out again by the tilt hammer; it is thus much improved in its qualities, and is fit for the finest instruments, but it cannot be welded.

Pure steel, ignited with charcoal powder, forms a gray, brittle and crystalline carburet of iron, containing 5.64 of carbon in 100; in several trials it was repeatedly formed, in the same proportions, and being therefore a definite compound it probably enters, in various proportions, into the composition of steel. The Indian *wootz*, is supposed to owe its peculiar properties to the bases of alumina and silica; it requires to be melted and equalized, before it will make fine edge tools.

(b.) *Case hardening*.—For the purpose of combining the strength of iron with the hardness of steel, manufactured articles are enclosed in certain animal substances, as horn shavings, hair, leather, &c. and being covered by clay, and contained in a proper box, they receive the requisite degree of heat; the outside is carbonized and the inside remains in the condition of iron; they are afterwards tempered in the usual way.

(c.) *Steel plates for Engraving*.—These are, by a particular process‡ decarbonized in the fire, and rendered soft; the engraving is then put on, and they are carbonized anew by being wrapped and heated in a proper composition and are afterwards duly hardened; this beautiful art has been brought to great perfection by Mr. Jacob Perkins. Steel is readily distinguished from iron by the action of an acid which dissolves the iron and develops the carbon,§ forming

* For the details I must refer to Gray's Op. Chem.; Thénard's Chem.; Aikin's Dic. and other large works.

† Now successfully performed in this country, and particularly by Mr. O. L. Clark, of New York.—See Am. Jour. Vol. XVII, p. 111. and Vol. XIX.

‡ The term used by Mr. Perkins, in conversation with myself.

§ Mr. Dalton did not find any residuum when he dissolved steel in acids, nor did the hydrogen, evolved by diluted sulphuric acid, contain any carbon; hence he was led to conclude that the peculiarities of steel do not depend on the absorption of carbon, but on a peculiar arrangement of its particles by a species of crystallization. These results are singular, and demand confirmation, if any thing can need it that has passed through the hands of Mr. Dalton.

a black spot; nitric acid is commonly employed for this purpose. In general, iron, in becoming steel, absorbs from $\frac{1}{16}$ to $\frac{1}{8}$ of its weight of carbon; cast iron contains from $\frac{1}{8}$ to $\frac{1}{4}$.

Steel can be alloyed with various metals, and some of the alloys are important; with $\frac{1}{8}$ of silver it retains the qualities of steel, and improved penknives are made of this alloy.*

With $\frac{1}{8}$ of platinum, steel is rendered tougher and harder. Rhodium, iridium and osmium produced valuable alloys. Some of these alloys, especially that of platinum, dissolve in acids with increased rapidity,† probably owing to the formation of a galvanic circle.

(d.) *Hardening of steel.*—Where the greatest hardness is required, it is obtained by heating the steel red hot and plunging it into cold water; it becomes also very brittle; to prevent decarbonization and scaling, it is, while heating, covered with charcoal or some similar thing. Various substances are used instead of water, as urine, acids, tallow, &c. and even cold air; or on account of their conducting power, the mere contact of metals is sometimes sufficient. The effect probably depends on a peculiar arrangement of the particles.

(e.) *Tempering of steel.*—When steel is hardened, as just described, it will become soft again, if it be heated up to the first point and then left to cool; but any intermediate hardness may be secured, by heating the article to the degree that corresponds to it, and then allowing it to cool of itself; this is called tempering and is usually judged of by the colors‡ that appear on the surface of the steel as it is heated; thus, a straw color corresponding to 430° or 450° F. denotes the proper temper for gravers, penknives, and razors, and other instruments, having a stout back and delicate edge; the first tinge of purple corresponds to 510° , and is adapted to table and carving knives. Tempering is frequently done by using an oil bath or one of fusible metal; the articles can be laid on the latter, and a thermometer indicates the proper degree of heat, and relieves the workman from the necessity of attending to the color of each article. Some articles are sufficiently tempered by a heat equal to that of boiling water.§

The elasticity of watch springs is obtained at a temperature of from 550° to 560° , by laying them on a plate of heated metal, or by burning charcoal or starch, and holding the spring in it till it becomes blue; if this blue film is removed by grinding it is said to destroy the elasticity.

Mere iron is not capable of being made very hard or very elastic.

* They seem to me more brittle than those made of common steel.

† Faraday, Phil. Trans. 1822.

‡ These colors depend on oxidation, and do not appear in oil or mercury, or in hydrogen or nitrogen gas.

§ Phil. Trans. 1818.

XIV. MISCELLANEOUS.—Medical uses.—Iron is friendly to the powers of life, and is frequently administered in medicine. There is little to add to what has been already said respecting its medical preparations.

Iron filings.—To free them from filings of brass and copper, they are rapidly drawn up through a sieve by a magnet; but this will not purify them entirely, and it is better to obtain them in places where these metals are not wrought, or to file good bar iron on purpose. The blacksmith's scales scarcely need any purifying, except by pulverizing and washing. The sulphate of iron, as prepared in commerce, sometimes contains copper, derived from the ore;* this is easily determined by ammonia, which, if copper is present, will give a sky blue color to the liquor, after the oxide of iron is precipitated and removed by the filter. The alkaline liquor of iron, made by mingling that metal, nitric acid, water and carbonate of potassa, and there will of course be an alkaline solution of oxide of iron mixed with nitre and precipitated oxide. Although as a chemical preparation, it appears to be absurd, if it has decided medical virtues, it ought to be retained.

Acetate of iron is made, by dissolving carbonate of iron in pure vinegar, and there is a tincture of the acetate of iron, made by mingling acetate of potassa, sulphate of iron and alcohol. See Coxe's Dispens. p. 291.

The tincture of muriate of red oxide of iron, made by mingling the red oxide with muriatic acid and alcohol, is an excellent chalybeate; a tartrate of iron and potassa is made by boiling carbonate of iron, or iron filings with cream of tartar and water; when there is not an excess of acid the taste of the iron is hardly perceptible.

Iron rust absorbs ammonia from the atmosphere.

The uses of iron in the common affairs of mankind are too numerous and obvious to need recital.

XV. POLARITY.—Attracted to the negative pole.

SEC. XXXI.—COPPER.†

I. HISTORY.

(a.) *Known from the highest antiquity*; only gold and silver were known as early. The domestic utensils and arms of the early nations, were generally made of bronze, or some other compound containing copper, alloyed usually with tin.

(b.) *Discovered, as is said, in Cyprus*, and hence the name cuprum or copper.

* Copper pyrites and other ores of that metal being frequently found with iron pyrites.

† Cuprum, Latin; alchemical name, Venus.

II. PROPERTIES.

- (a.) *Color brownish red*; * *receives a high lustre from polishing.*
 (b.) *Taste and smell nauseous*; hands that have touched it impart the smell for a good while to the nostrils; poisonous in every form and said to be instinctively rejected by animals.
 (c.) *Very sonorous*, elastic, tenacious, *malleable and ductile*; leaves of it may be made so thin as to be blown away by the wind.
 (d.) *Sp. gr.* 8.830, (Lewis); 8.895, (Hatchett); 9. Japanese, (Cronstedt); 8.434, (Thomson); sometimes in commerce 8.6; † *sp. gr. increased by hammering.*
 (e.) *Rather soft*; will not strike fire with the flint. ‡
 (f.) *Texture granulated* and liable to blisters.
 (g.) *Tenacity inferior to that of iron*; superior to that of platinum, silver and gold; a wire of $\frac{1}{16}$ th of an inch in diameter, sustains 300 lbs. §
 (h.) *Conducts heat very well*; *melts at a full white heat*, (usually stated to be 27° Wedgwood,) and if urged, *evaporates*, in visible fumes; it can be melted on charcoal by the mouth blowpipe, and before fusion shows prismatic colors.
 (i.) *Crystallizes*, by slow cooling, in quadrangular pyramids; when native, it is not unfrequently crystallized.
 (j.) *When cast*, unless very hot, it is prone to be *porous*; at ignition it is impressible, and bears the hammer. ||
 (k.) *Great capacity for heat*, and so much is latent in its fluid state as to vaporize water with explosive rapidity. ¶

III. RELATION TO OXYGEN.—*Combustibility.*

- (a.) *Copper is a combustible metal*; pieces of it thrown among burning coals, instantly tinge the flame green,** and so do most of the cupreous salts, especially if mixed with alcohol. ††
 (b.) *Under the compound blowpipe it melts and boils, and burns with great splendor*, emitting a green flame and light almost insupportable by the eye; if after it is white hot, the hydrogen gas be shut off, it continues to burn in the oxygen gas alone; but the green flame is not so apparent as when the hydrogen gas is used with the oxygen; the fumes must be carefully avoided.

* No other metal except titanium has a red color.—Turner.

† Average of these five numbers, 8.752; coming very near to that assigned by Dr. Turner, 8.78.

‡ Therefore used for making the nails, hoops, hammers, chisels, and other instruments employed in the manufacture of powder.

§ Fourc. VI, 817.

|| Used in this state in the hasty coinage of the Romans; frequently in camp, with the general's die.

¶ Hence the moulds in which cupreous metals are to be cast are dried with great care, and even in some instances, ignited.—Black. This liability is however denied by some artists who cast copper and its compounds.—J. T.

** Hence it is often used to tinge artificial fire works.

†† Charcoal, or a sponge, filled with such a solution, burns with a splendid green, and becomes covered with metallic copper; it is said that the blue cupreous salts tinge flame green; the green blue; this is true in some cases, but there appear to be some exceptions.

(c.) *If the white hot globule be thrown from the charcoal into a tall jar or wide tube of water, whose bottom is protected by sand, it will pass, in full ignition, through a column of the fluid two feet high, and will remain, for some time, ignited on the bottom.*

(d.) A strong electric or galvanic discharge burns a copper wire.

OXIDES.

(a.) *Copper is tarnished by air and moisture, and acquires an obscure glossy skin, like a varnish, and in a long time becomes covered with a coating of green sub-carbonate.**

(b.) *A plate of ignited copper is promptly incrustated by oxide, which cracks as the metal cools, and falls off in scales, especially if alternately heated and plunged into water.†*

There has been difference of opinion as to the number of the oxides of copper, but it is now generally agreed that there are only two.‡

1. *Protoxide—red oxide; when hydrated, yellow.*

(a.) *Formed by distilling to dryness, and even to redness, the muriate of copper; the residue, thoroughly washed, is heated with an excess of sub-carbonate of potassa, when the hydrated protoxide precipitates, in a yellow powder.*

(b.) *The permuriate§ of copper with free muriatic acid and copper filings, is placed in a stopped vial; or 57½ parts of peroxide of copper are triturated with 50 of metallic copper, precipitated by iron, and 400 of muriatic acid are added and dissolved by heat in a close vessel; and then the hydrated oxide is precipitated by potassa.*

(c.) *By igniting in a close vessel, metallic copper, 64 parts, with peroxide 80, both finely divided; or by boiling a solution of the acetate with sugar which takes one equivalent of oxygen and leaves the protoxide, to subside.*

(d.) *Properties.—As a hydrate, yellow; melted below ignition; color red, when water is expelled; absorbs oxygen readily; with the muriatic and probably other acids, forms colorless proto-salts, from which alkalies precipitate a yellow hydrate. Ammonia dissolves the oxide and gives a colorless solution.*

* Which defends the copper beneath from any farther action; this is the condition of most of the ancient copper medals, which appearance, the venders vainly endeavor to imitate by art in modern coins; it requires the long continued concurrence of both air and moisture, to give them their peculiar appearance. A polished bar of copper is tarnished by various shades of color when heated.

† It is common, in finishing the copper stills, to heat them by a fire made inside, till the copper is oxidized, and then to dash on buckets of cold water; scales of oxide fly off, from the rapid contraction of the metal, and leave the copper with a beautiful red surface.

‡ Thénard (Chim. V. II, 549,) has given, much in detail, a method of forming a tritoxide of copper, by the action of oxygenized water upon the nitrate of copper, or the hydrated peroxide, but his conclusions have not been adopted in the most recent works.

§ Formed by dissolving peroxide of copper in muriatic acid.

(e.) *Exists native*,—in mass, and in deep red brown octahedral crystals,* and in light red fibres, from which a good heat of the mouth blow pipe, upon burning charcoal, evolves the metallic copper. In the native salts of copper, (except the carbonates,) the acids are combined with the peroxide.

(f.) *Composition*.—Copper 1 equiv. $64 + 1 \text{ oxy. } 8 = 72$, its equiv.; per cent. copper $88.89 + \text{oxy. } 11.11 = 100$.

2. *Peroxide; black oxide; when hydrated, blue.*

(a.) Formed by calcining under a muffle, the scales of oxide of copper, produced by heat and air.†

(b.) By decomposing the per-salts of copper, particularly the nitrate, by potassa and igniting the residuum.

(c.) By simply igniting the nitrate, when its acid is decomposed and expelled.

(d.) *Properties*.—*Color brownish or bluish black; fusible at a heat above redness*; at a high heat, probably becomes protoxide; by heat and combustibles, readily reduced to the metallic state; insoluble in water; combines with most acids, and its salts are green or blue; soluble in ammonia, forming a deep blue solution.‡

(e.) *Composition*.—Copper 1 equiv. $64 + 2 \text{ of oxy. } 16 = 80$ its equiv.

IV. (a.) *WATER, when pure, has no action on copper*; even at a white heat, copper does not decompose water, and no hydrogen gas is produced.

(b.) But, by the joint action of air and water, it is oxidized, and a line of green oxide, or rather carbonate is formed, doubtless by a galvano-chemical action.§

(c.) *Water unites with oxide of copper forming a hydrate*. Potassa precipitates it blue|| from the nitrate: it must be largely washed with boiling water, and when dry it will shrink like alumina, but retains its color; it appears to consist of 1 equiv. of peroxide, with 3 of water; at a high heat the water is expelled, and the remaining oxide constitutes 3 parts out of 4.

V. *COMBUSTIBLES*.—*Copper combines with sulphur and phosphorus.*

* Found very beautiful in the mines of Cornwall; the Cornish gentry place groups of these crystals as ornaments in their houses along with other beautiful minerals of that county. This red or ruby oxide, occurs also in Connecticut and New Jersey.

† They are an imperfect oxide, or rather a mixture of black oxide 62 and copper 88.

‡ Peculiar to this metal.—(Turner.) Nickel (as indeed the same author elsewhere observes,) gives a similar solution, but it is a paler blue, not azure, and it is not permanent, as the suspended oxide eventually precipitates.

§ This accords with familiar experience in common life. Hence no alimentary fluid should be kept in open copper vessels.

|| The blue hydrate retains its color if prepared in glass or earthen vessels; but in wooden vessels, it turns black, if exposed to the light. I have had the precipitate from 200 gallons of solution, change to black in the course of an hour or two.—G. C.

1. *Phosphorus.*

(a.) *Phosphuret of copper may be formed in the modes already described, (page 122,) either by the heated metal and phosphorus, or the metal, phosphoric glass and charcoal.*

(b.) *Properties.*—*Brilliant, brittle, white, very hard; not ductile; sp. gr. 7.122; crystallizes in prisms; more fusible than copper; heated in the air, crumbles and becomes phosphate of copper.*

(c.) *Composition; 20 phosphorus to 100 metal*—(Pelleter); the equivalents are in the ratio of 20 : 106½, so that this early experiment is not very incorrect.

2. *Sulphur.*—There are two sulphurets of copper.

1. *Proto-sulphuret.*—*Formed by heating equal parts of copper filings, and sulphur, in a crucible.**

(a.) 3½ parts of copper filings with 1 one of sulphur being mixed in a glass vial, flask, or tube, and then gradually heated, the substances melt and at the moment of combining emit a deep red light.† Copper leaf is ignited as brilliantly in the vapor of sulphur as iron wire in oxygen gas.

(b.) *Properties.*—*Color gray; crystals hexahedral prisms; more fusible than copper; not decomposed by heat, but this sulphuret combines with oxygen and becomes sulphate or subsulphate.*

(c.) *Composition.*—Copper 1 equiv. 64 + 1 of sulphur 16 = 80 its equiv; for 100 of copper there are 25 of sulphur.

(d.) *The proto-sulphuret exists native, in the copper glance or gray sulphuret of copper, and in the copper ores of which, along with sulphuret of iron, it forms nearly one half.*

2. *Deuto or bi-sulphuret of copper.**Processes.*

(a.) By passing sulphuretted hydrogen gas through a solution of the per-sulphate of copper.

(b.) By rubbing, in the cold, the powder of sulphuret of copper, with strong and pure nitric acid.

* Formerly by heating to dull redness for one hour, plates of copper, alternating with flowers of sulphur; the product was brittle, and of the color of iron; it was called *ae veneris* in the shops, and was prepared for dyeing and printing cloths.—*Four. VI. 346.*

† Equal parts (Thénard;) by the equivalents, sulphur is but 1-5 of the whole compound, but in forming the sulphurets an excess of sulphur is commonly used that we may be sure to have enough.

‡ This emergence of heat and light happens equally, in a vacuum or in any gas, but it is scarcely proper to call the appearance a combustion, for the product is still combustible and is not a sulphate of an oxide but a sulphuret of the metal. See Remarks on combustion, pp. 98. 99.

§ Thénard says that in the copper pyrites it is in the state of proto-sulphuret. (*Chim. Vol. I. p. 377.*) while Dr. Turner (3d. Am. Ed. p. 358.) says it is in the condition of a bi-sulphuret.

(c.) *Properties*.—As formed by this last process, it is a greenish black powder.* By a red heat, in close vessels it loses half its sulphur and becomes proto-sulphuret.

(a.) *Composition*.†—Copper 1 equiv. 64 + 2 of sulphur, 32 = 96 its equiv.; per cent. copper 100, sulphur 50.

VI. ACIDS.—*Salts of Copper.*

Many of them have been long known and are well understood.† Every acid acts upon copper, in some degree, and in some circumstances§ and discolors it. Its salts are generally either blue or green.

1. *Sulphuric acid*.—*Sulphate of copper*.—*Blue vitriol*.

(a.) *In the cold, no action even when concentrated, but with acid 2, and metal 1, by a boiling heat, this metal is oxidized and dissolved*, while sulphurous acid gas escapes, forming a fine blue solution.

(b.) *In the large way the copper is oxidized by igniting it in an oven*; the scale of oxide is then beaten off and the copper is heated again till the whole is thus oxidized; the scales,|| heated in the acid, will partially dissolve without decomposing the latter.

(c.) *Procured by evaporation from natural waters*, in the copper mine districts of some countries, as England, Ireland, Hungary and Sweden.

(d.) *Or, copper pyrites¶ are roasted with access of air and moisture*; the sulphur is acidified, the copper oxidized, and a bi-sulphate** is formed, and extracted by solution and crystallization.††

Properties of the blue vitriol, (sulphate of copper.)

(e.) *This is a bi-sulphate of the peroxide; the crystals‡‡ being oblique prisms*, whose base is an oblique parallelogram, appear like rhomboids; they are often large and beautiful.

* Faraday Eng. Quart. Jour. XXI. 183. and H.

† A bi-sulphuret of copper is constantly forming in the crater of Vesuvius, along with many metallic and other bodies; it happens after an eruption, the heat being still active below but dormant above, so that the sublimed substances can be condensed. Ann. de Ch. et de Ph. Tome 35. p. 109.

‡ The alchemists called them salts of Venus.

§ Some very curious observations of Dr. John Davy, (Jameson's Edinb. Jour. 1830,) tend to show that the atmosphere, probably by a galvano-chemical action, is very efficient in producing the salts of copper, and that even with the three mineral acids the action is either null or slight, provided the air is excluded.

|| The composition of these scales is variable; they are often a pure protoxide, and when treated with hot sulphuric acid become peroxide of copper, which dissolves and finely divided metallic copper subsides. Their texture is crystalline and they readily dissolve in ammonia, and give, in close vessels, a colorless solution.—A. A. H.

¶ By mixing moistened copper filings and flowers of sulphur, a spontaneous sulphatization will be accomplished in the course of some time.

** In France, they sprinkle moistened sheets of copper with flowers of sulphur, and having heated them red hot in a furnace, plunge them, while hot, into cold water, which causes the sulphuret to flake off; then the sheets are sprinkled and heated anew, and so on; sometimes it is obtained, by passing the vapor of sulphur through cylinders filled with pieces of copper: this sulphuret changes into sulphate by the action of the air, and the salt is dissolved by water.

†† If iron is present it is precipitated by the addition of deutoxide of copper, (Thénard, Vol. III. p. 197, 5th Ed.)

‡‡ The solution is easily crystallized by evaporation, and, even simply by cooling.

(f.) *It has been called a super sulphate*; because it reddens vegetable blues; the black oxide of copper will saturate the excess of acid and render the salt neutral.

(g.) *Color deep rich blue, taste styptic, metallic and nauseous*; used as a caustic; *soluble in 4 parts of water at 60°, in 2 at 212°*; insoluble in alcohol; slightly effloresces.*

(h.) *Suffers the aqueous fusion*; becomes a bluish white powder, and by an increased heat the acid is expelled undecomposed,† and the black oxide remains.

(i.) *Earths and alkalis and their carbonates, precipitate a blue or bluish grey hydrated oxide*; it becomes green in the air by absorbing carbonic acid. The pure alkalis dissolve the precipitate.

Ammonia does it promptly, and *forms the aqua celestis* of the apothecaries, of a beautiful blue color; *ammonia* is in this way an *excellent test of copper*, which it discovers in very minute proportions; 1 gr. will tinge 2 lbs. of water.

(j.) *Muriate of ammonia and blue vitriol, equal parts being mixed and dissolved in warm water, the solution is yellow, while warm, but becomes green on cooling;|| it is a sympathetic ink.*

(k.) Many metals, as *zinc, tin and iron*, (and eminently the latter) *precipitate copper* from its solutions; a clean iron plate, on being immersed in a cupreous solution, is instantly covered with copper.¶

(l.) *Composition*.—Peroxide 1 equiv. 80 + sulphuric acid 2 equiv. 80 + water 10 equiv. 90 = 250 its equiv.; per cent. peroxide 32 + acid 32 + water 36; without water, peroxide 1 equiv. 80 + acid 2 equiv. 80 = 160; per cent. peroxide 50.90, acid 49.10.—*Berzelius*.

It appears then, that blue vitriol is a bi-sulphate and some choose to call it a bi-per-sulphate.**

* Only superficially in the air, its surface becoming covered with a greenish white powder; fine specimens of the crystals lose their beauty in that manner, but being redissolved in water, beautiful crystals are again obtained; varnish will preserve these from efflorescence.

† It is generally stated, that the sulphuric acid may be obtained from it by distillation undecomposed, but Laugier (Cours de Chimie, Vol. II. p. 242,) says "produit molas d'acide sulfurique que la sulphate de fer, et une plus grand quantité d'acide sulfurique et d'oxygene, dans la proportion de 2 a 1; on a pour residu du peroxide de cuivre."

|| Lines drawn with it on paper, are invisible while cold, but become yellow on being heated, and again disappear on cooling.

¶ Iron is employed to separate copper from its native sulphuric and other saline solutions. As it is often dissolved in the waters that run from mines, it is not unfrequently detected by meeting, accidentally, with iron which throws down the copper.

** It is obvious that the refinements of a significant nomenclature are sometimes embarrassing, requiring frequent changes with the progress of discovery, and presenting names which although accurate, are inconveniently long; they also compel us to return occasionally to ancient *proper names*, such as alum, calomel, common salt, white, green and blue vitriol, &c. Where the old names are short and involve no erroneous idea, it is well to retain them; and the systematic name, being annexed, will always answer the purpose of a concise definition.

(m.) *A sub-sulphate* (composed of peroxide 2 equiv. 160 + acid 1 equiv. 40=200,) was obtained by Mr. Proust by adding potassa to the solution of the sulphate, but not enough to saturate the acid; the sub-sulphate is a green precipitate; if the acid is saturated, the precipitate is a blue hydrate.

(n.) Dr. Thomson mentions a *quadri-sulphate*, composed of 4 equiv. of acid 160 + 1 of peroxide 80=240.*

(o.) *Medical uses*.—An escharotic, a styptic, and in very small doses used as an emetic; being a decided poison, it should be employed with great care.

2. *Sulphurous acid; no action on copper*; if sulphurous acid gas be first passed through a small vessel of water to wash out sulphuric acid, it *unites with peroxide* of copper suspended in water, and forms a green acid solution of sulphite, and small red crystals are precipitated; composition, protoxide 63.84 + acid 35.16=100.†

3. *Nitric acid dissolves both copper and its oxides*, with energy; the oxides are dissolved without effervescence.

(a.) *Acid 1, with water 2, copper in pieces*; at first, apply a low degree of heat and remove it as soon as the action begins.‡ (See Vol. I, p. 453.)

(b.) *Nitric oxide gas*, holding a little copper in solution, is *disengaged*, as already described. (Id.) Ammonia is also formed.

(c.) *Properties*.—The solution is of a *blue* color, richer than the sulphate, or it is at first green§; crystals in long parallelopipeds are obtained by evaporation; their sp. gr. is 2.174.

(d.) *Taste intensely acrid* and metallic; very caustic, and used as an escharotic.

(e.) *The crystals deliquesce*, are very soluble in water, and soluble also in alcohol; at about 100° suffer the aqueous fusion; by a longer heat they lose water and some acid, becoming in this manner a less soluble sub-nitrate.

(f.) *Scintillate a little on burning coals*; paper or charcoal, imbued with the alcoholic solution, burns with a rich green flame, and becomes covered with metallic copper.

(g.) *Detonate with phosphorus*, by percussion.||

* Ann. Philos. N. S. I, 244. It unites with other salts, and forms double salts; the sulphate of iron and copper, closely resembles bi-sulphate of copper, in form.—A. A. H.
† Chevreul. Ann. de Ch. 33. p. 181, and H.

‡ It does not readily act if highly concentrated, but when it does come on, the action is so violent as to be dangerous.—Laugier.

§ Green at first, from the solution of nitric oxide gas; it becomes blue by being heated or kept, until the gas is expelled, the proper color of the salt being blue.

|| A hot hammer insures such effects; but from experience I would recommend the omission, of this class of experiments, as the phosphorus both deflagrates and flies laterally many yards, in burning jets, dangerous to spectators and to the operator, unless well proected.

(h.) *Pulverized and wrapped in tinfoil*, there is *no effect*, if the nitrate is dry, but, if moistened a little, as with a camel's hair pencil, and then wrapped again, using some pressure, it acts with energy, corroding the copper, bursting forth in fumes, and even sometimes with scintillations. This effect is due to the nitric acid.*

(i.) *Bibulous paper, saturated with a solution of this nitrate, becomes ignited while drying*, although still wet, and at a distance of a yard or two from the fire; as it burns, the ashes are covered with metallic copper.

(j.) *Decomposed by alkalis and earths*; the precipitate by potassa in excess, in a dilute solution of the salt, is a beautiful blue hydrate. The re-solution, by ammonia, is exceedingly beautiful; the precipitate is at first greenish or bluish white, but on the addition of a little more ammonia, the oxide is re-dissolved and the fluid becomes more intensely blue than before.

(k.) *Composition*.—Peroxide of copper 42.61 + acid 57.39 = 100. (H.) In crystals, acid 2 equiv. 108 + 1 equiv. of peroxide, 80 + 14 equiv. of water, 126 = 314, its equivalent.—*Thomson*.

(l.) *The nitrate, when ignited, gives peroxide of copper*, the acid being expelled.

(m.) A fresh stick of phosphorus, placed in a solution of the nitrate, becomes covered with metallic copper, sometimes in crystalline grains.

Sub-nitrate.—When potassa, less than will saturate the acid, is added to nitrate of copper, or when it is distilled in a retort, the salt becomes first blue, and then, by agitation, green; it is insoluble in water. Sulphuric acid separates the nitric acid. Its composition appears to be very nearly 1 equiv. of acid, 4 of peroxide and 8 of water. (H.)

Verditer.—*The hydrate of copper, with a little lime, forms the beautiful blue paint used in making figured paper*.—There are two sorts; the preferable one is made from the nitrate of copper, formed by the refiners in the process of parting gold and silver; the other from blue vitriol. To a solution of nitrate of copper, add lime, in powder, with agitation, leaving a little excess of the nitrate; after subsidence, decantation and washing, the green precipitate is ground on a color stone with about 4 or 5 per cent. of quick lime; it instantly acquires a lively blue color; if it is too stiff, water may be added; if

* On tinfoil, as large as half a sheet of paper, lay a heap of the pulverized nitrate, a little moistened, and over it a few filaments of tow, then double up the tinfoil around it on all sides, twisting it as tight as may be without breaking; in a short time it will grow hot and the other effects will follow. (Aikins.) The nitric acid, in a concentrated state, is reluctant to act on metals, and this effect appears to depend on the agency of water, for even the concentrated hot solution does not act on tinfoil, until a little water is added. (Murray.)

too blue, lime. It is probable that the above is an approximation to the process used in the arts, which is kept a secret.* It would appear that the blue verditer, when precipitated by carbonate of lime, is allied, in its composition, to the native blue carbonate of copper, which is peroxide of copper 67.6, carbonic acid 24.1, water 5.9, moisture and impurities 2.4=100. (H.)

4. *The muriatic acid.*—There are two muriates of copper, the proto- and the per-muriate.

1. *Per-muriate.*

(a.) *The muriatic acid does not attack copper, except with the aid of heat,† and then but feebly.*

(b.) *The solution is more easily effected by the aid of heat; some hydrogen gas escapes, mixed with some muriatic acid gas, and a portion of copper is dissolved. This however is not a good process; it is almost impossible to obtain a good solution in this way.*

(c.) *The peroxide, especially if hydrated, is easily dissolved in muriatic acid; color of the solution a pure grass green,‡ whereas the nitrate§ and sulphate are blue.*

(d.) *By evaporation, affords green crystals, rhomboidal prismatic parallelopipeds, or needles in bundles.*

(e.) *Acrid and caustic; both water and alcohol when boiling, takes up their own weight; sp. gr. 1.67; very soluble; deliquescent; not decomposed by water; easily melts, and by a very strong heat chlorine is expelled.*

(f.) *The alkaline bodies, as well as zinc, iron, and other easily oxidable metals, and several compound salts, affect it in the same manner as the sulphate and nitrate.*

(g.) *Composition.* Peroxide 40 + acid 24 + water 36; corresponding very nearly with 1 equiv. of base, 2 of acid and 6 of water, which would make it a bi-per-muriate. (H.)

(h.) *Copper plates, corroded by muriatic acid vapor, become incrustated by a green coating which is regarded as a true muriate,¶ containing 1 equiv. of acid and one of peroxide; it yields the latter by alkalies after being dissolved in muriatic acid. (H.)*

* See Aikins' Dict. and Gray's Op. Chemist.

† It may be kept in a vessel of copper, closed and full, without affecting it, but if the air have access, the copper is slowly corroded, and especially if it is sprinkled with muriatic acid and exposed to the air; a green crust then forms, which is easily dissolved in muriatic acid.

‡ Thénard says, its solution is bluish, but becomes green by the addition of muriatic acid; that if the acid is in great excess and very strong, it is brown; if diluted, green; if the acid be saturated, blue.

§ Except, as already explained, the nitrate is at first green, from its holding nitric oxide gas in solution.

¶ Muriate of copper is yellow when carefully dried, and disappears by attracting water; it may therefore be used as a sympathetic ink, (Black) a mixture of it with muriate of cobalt, would, probably, form a very beautiful sympathetic ink.

(i.) The muriate of copper, if decomposed by a little potassa yields a *sub-muriate*, which falls as a green powder; if the alkali predominate, the hydrate of copper is obtained; it is a sub-muriate of copper, that is formed by sea water upon the sheathing of ships, and the galvanic protectors of Sir H. Davy, were intended to guard against this occurrence.

The green arenaceous muriate of copper of Peru, district of Ramcapa,* is supposed to be nearly a sub-muriate. It is composed of peroxide of copper 73 + muriate 16.2 + water 10.8=100. (H.)

2. *Proto-muriate*.†

(a.) *Formed by* placing, in a closed vial of *muriatic acid*, a triturated mixture of the *black oxide of copper* 57.5 parts, and 50 parts of *copper powder*, precipitated by iron from the muriate or sulphate.

(b.) By digesting a solution of per-muriate of copper with filings of the metal.

Properties.

(c.) *Solution colorless*; but by absorbing oxygen from the air becomes green; decomposed by water, giving a white precipitate; that with alkalis is orange colored.

(d.) *Composition*.—Protoxide 73.88 + (copper 65.80 + oxygen 8.08) + acid 26.12=100.

5. *The acetic acid does not readily act on copper*.‡

With the aid of the air, the metal is however slowly oxidized, by this acid, and then combines with it. This is the source of the *verdigris* (acetate,) and of the *distilled or crystallized verdigris* (binacetate,) of commerce.

Preparation of verdigris, &c.; Acetates of copper.

The refuse grapes and husks are fermented with sour wine, and strata of this mass are laid, alternately, with plates of copper of 6 by 5 inches, and $\frac{1}{4}$ of an inch thick. Being left a sufficient time, they are then taken out and placed edgewise in a cellar, where they are sprinkled with sour wine; the verdigris swells up and is afterwards scraped off and put into sacks of leather for exportation. The copper plates are then again corroded and treated in the same manner, and so on.§

* Where it is used for sanding paper. Ann. de Ch., et de Ph. V. 18, p. 442.

† Formed also by adding recent muriate of tin to the per-muriate of copper; a white muriate is precipitated, which by the addition of an acid, forms a colorless solution; the muriate of tin attracts one equivalent of oxygen.

‡ Mentioned here on account of the important salts which it forms with copper; this acid is known to every one and no inconvenience can arise from the anticipation.

§ Instead of the stalks and husks, the marc or cake that remains in the wine press is often employed; it is preserved for the purpose and used when wanted; it ferments and produces acid enough to corrode the copper; the latter is previously hammered to prevent the scaling of metallic copper when the verdigris is detached; the copper plates are heated and stratified with the marc in earthen pots, sixteen inches high and fourteen wide, and capable of containing 30 or 40 lbs. of copper plate; and if

Properties of verdigris; acetate of copper.

(a.) *Pulverulent, pale grayish green or blue*, not altered by the air, insoluble in alcohol.

(b.) *Verdigris is composed essentially of minute blue crystals of a silky lustre*; they are partly soluble in water and partly insoluble; the latter portion is a sub-acetate, and is eventually decomposed by cold water. In verdigris the combination appears to be of 1 equiv. of acid with 1 of peroxide, and when water is added there is a decomposition; it dissolves 56 pr. ct. of binacetate, and the remainder, as a sub-acetate, falls a green insoluble powder.

(c.) *This precipitate of sub-acetate* is decomposed by sulphuric acid, which expels the acetic acid; by potassa, which precipitates the oxide, and by distillation, which subverts the composition and liberates the acid. The continued action of water decomposes this salt entirely.

(d.) *Composition*.—Protoxide, 1 equiv. 80+ acid 1 equiv. 50+ water 6 equiv. 54=184 its equiv.; per cent. acid, 28.38, peroxide, 43.25, water, 28.45.

(e.) The verdigris* of commerce contains then, acetate of copper, but affords by the action of water, a soluble binacetate and an insoluble sub-acetate.

*Crystallized or distilled verdigris; binacetate of copper.**Preparation.*

(a.) That part of verdigris which is dissolved by water contains this salt, and by evaporation affords it in crystals.

(b.) *By dissolving verdigris in vinegar*; or, the oxide of copper may be dissolved in distilled† vinegar, but this is not of so beautiful a green as when prepared as follows.

(c.) *Fresh moist verdigris is usually dissolved*, with the aid of a boiling heat, in vinegar distilled from sour wine, and transferred into a copper boiler for evaporation and crystallization.‡

the plates are new they are rubbed with a rag dipped in verdigris water to prevent the product from being black. When the cake becomes white, the plates, now covered with silky crystals, are placed upright in a cellar for 2 or 3 days, then dipped in water, then drained and dipped again, and so on, every two or three days, for six or eight weeks. The manufacture is a family business, carried on by the women, on the wine farms, near Montpellier and Grenoble in France.

* Verdigris is much used in dyeing. This salt, in common with all the salts of copper is extremely poisonous, and therefore copper vessels are unfit to contain vinegar, pickles, &c.; even sweet preserves may become acid and corrode the copper.

† Whence probably the name crystals of distilled verdigris.

‡ Sticks, split in four, and separated at one end but united at the base, are then placed vertically in the bath, and after some days, are covered with rhomboidal crystals of a blue color, often very large and beautiful. The distilled verdigris and sugar of lead are both formed by the action of vinegar; in the first case upon a sub-acetate, in the second upon a carbonate. Verdigris is used as a pigment for coarse purposes, principally in varnishes; in this country it is much used in painting window blinds, but it does not stand well out of doors; the distilled verdigris is used for similar purposes and has a finer color. Both are employed to afford the strong acetic acid being decomposed by sulphuric acid, or even by heat alone.

Properties of the distilled verdigris or binacetate of copper.

(a.) *Crystallizes* in four sided truncated pyramids or rhombic octahedra; color a beautiful bluish green, taste sweetish and styptic.

(b.) *Soluble* in 20 parts of water at 60°, in 5 at 212°; soluble in alcohol.

(c.) *Burns* on a red hot iron with a green flame, and noxious fumes; imparts the same color to other combustible fluids holding it in solution.

(d.) *Effloresces*;—gives out concentrated acetic acid* by distillation, per se, but better with the aid of sulphuric acid, or bi-sulphate of potassa.

(e.) *Calcined* by itself, with access of air, it leaves peroxide of copper.

(f.) *Composition.*†—Acetic acid 2 equiv. 100 + peroxide of copper 1 equiv. 80 + water 3 equiv. 27 = 207; per cent. acid 50.11, oxide of copper 37.77, water 12.12. According to Berzelius and Dr. Ure, there are but 2 equivalents of water. Berzelius has indicated three other acetates of copper, but they appear not to be particularly important.‡

6. *Carbonic acid unites with the oxides of copper*, although it does not attack the metal.

(a.) *The green crust*, formed on copper by air and moisture, is a carbonate, and not, as many suppose, verdigris.§

(b.) *Found native*, both blue and green, in very great beauty; the green is known to mineralogists by the name malachite; the blue is called azure or blue carbonate.

(c.) *Formed by double exchange*, between carbonate of an alkali and a solution of any cupreous salt, as of the sulphate or nitrate; precipitated yellowish green from a hot, and bluish green from a cold solution.

(d.) *Redissolved in any acid with effervescence*; if however a carbonate of copper is boiled with water it loses so much carbonic acid as to become a sub-carbonate, dissolving in acids with very little effervescence.||

(e.) *Composition.*—Peroxide of copper 1 equiv. 80 + carbonic acid 1 equiv. 22 + water 1 equiv. 9 = 111; per cent. 71.7 oxide, 19.7

* The acetic acid, thus obtained, is fragrant, but is usually contaminated towards the beginning with copper and with an empyreumatic odor; the middle portions are the best and should be preserved; the residuum is often a pyrophorus and is a mixture of copper nearly reduced, and charcoal.

† Phillips, Ann. Ch. et Ph. Vol. 21. p. 214.

‡ Ann. Philos. N. S. Vol. VIII. p. 188 and Ann. de Ch. et de Ph. Vol. XXVI, p. 40.

§ It is usual to call all green incrustations on copper, verdigris; usually they are carbonated oxide, but they may in particular cases be real verdigris, provided acetic acid or any thing capable of producing it has been concerned.

|| Gay-Lussac. Ann. de Ch. et de Ph. XXXVII, 335.

acid, 8.6 water. This appears to be very nearly the composition of the native green carbonate, namely, 72.2 peroxide, 18.5 acid, and 9.3 water. H.

7. *Phosphoric acid.*

(a.) *Native phosphate of copper is found of a green color, dissolving in acids without effervescence.*

(b.) *Formed by phosphoric acid and oxide of copper, but more easily by mingling phosphate of soda and sulphate or nitrate of copper,* when a blue phosphate will be precipitated.*

(c.) *Its composition is 1 equiv. peroxide $80 + 2$ of acid, $56 + 1$ of water $9 = 145$ its equiv.; it is a bi-phosphate while the native is simply a phosphate with 1 equiv. of acid and 2 of water. (H.)*

8. *Ferro-prussic acid.*

(a.) *The prussiates give a beautiful brown precipitate from the cupreous solutions.†*

(b.) *To form it, the muriate of copper, dissolved in 10 parts of water, is decomposed by prussiate of lime; the precipitate is washed and dried without heat.*

9. (a.) *Arsenic acid, unites with the oxide of copper, and the white oxide of arsenic or arsenious acid form with it a pigment, known from its discoverer, by the name of Scheele's green.*

(b.) *Dissolve 24 parts of pearl ashes and 11 oz. of arsenic in hot water, and filter; then add a watery solution of 24 parts sulphate of copper, by little and little, using constant agitation, with a glass rod. After subsidence, decantation,edulcoration and drying, $18\frac{1}{2}$ oz. of the green pigment will be obtained.‡*

VII. CHLORINE.—*There are two chlorides of copper, and both are formed when metallic copper, in filings or leaf, is burned in warm chlorine gas.*

1. *Proto-chloride.*

(a.) *Two substances, (chlorides,) are formed; one like common rosin, and which Boyle (1666) called the rosin of copper. (H.) One end of a spiral of large copper wire is fixed in a stopper and the other, after being heated, is plunged into a vessel of chlorine gas; the copper becomes inflamed and produces a chloride, in the form of thick revolving clouds, marked, here and there, by brilliant sparks. It is obvious that the chloride may be prepared by passing dry chlorine gas over copper wire, contained in a heated glass tube.§*

* A solution containing 176 parts phosphate of soda and 50 of potash, should be mingled with one containing 250 bisulphate of copper.—A. A. H.

† Mr. Hatchett recommended it as a paint. It is found to stand very well in both oil and water and to be more beautiful than any brown pigment known.

‡ Mentioned as a test of arsenic, p. 193.

§ Thénard, 5th ed. Vol. III, p. 371.

(b.) *By heating the proto-muriate, (to redness,*) in a retort, or by carefully evaporating and fusing it. (H.)*

(c.) *By distilling a mixture of equal parts of corrosive sublimate and copper filings; the chloride remains in the retort.*

(d.) *Insoluble in water, soluble in muriatic acid; color dark brown, but becomes green in the air, and by slow cooling becomes yellow and semi-transparent.*

(e.) *Composition.*—Copper 64 + chlorine 36 = 100, being one equivalent of each, and the composition of the chloride and of the oxide gives the same number for the equivalent of copper.

2. *Per-chloride.*

(a.) *Formed by evaporating the per-muriate, at a heat below 800°.*

(b.) *Color yellowish or greenish; in water affords a green solution, which is, in all respects, the per-muriate.*

(c.) *Heated in a tube, with a small orifice, chlorine is expelled and proto-chloride remains.†*

(d.) *Composition.*—Per cent. 47 copper, chlorine 53; it is supposed to consist of 2 equiv. of chlorine and 1 of copper, which ought to give for the chlorine 72 and copper 64 = 136; whereas analysis has given the chlorine at 67.

(e.) *Chlorate of copper was formed by dissolving copper in chloric acid; it was bluish green, deliquescent and difficult to crystallize. (H.)*

VIII. (a.) *ALKALIES, if caustic, favor the oxidation of copper, and as before stated, they decompose the cupreous solutions.*

(b.) *The action of ammonia on the precipitated hydrate, in redissolving it, has been already mentioned, but its action on metallic copper is very peculiar.* Copper filings, in contact with caustic ammonia and air, especially with agitation, as in pouring from one glass into another, will soon give a beautiful blue solution.‡ If the filings and ammonia entirely fill a closed bottle, there will be no change, and if the blue color has begun to appear, it will, if shut from the air, by and by, disappear; by renewed contact with the air, the color will re-appear, and so on. After it has appeared, the addition of copper filings will discharge the color. These appearances are explained by the joint action of air and the alkali; by the action of the entire fluid in producing dilution, and by the abstraction of oxygen by fresh copper filings.

(c.) *Ammoniuret of copper.*—A medical preparation, which bears this name, is made by rubbing in a glass mortar, sulphate of copper 1 part + 3 concrete carbonate of ammonia; they effervesce, become nearly liquid, and form a blue mass.§

* Thénard.

† Webster.

‡ Articles of jewelry, composed of copper and gold, are cleaned by boiling them in ammonia water.—A. A. H.

§ Employed in medicine as an anti-spasmodic, in epilepsy, &c. It is a compound of sulphate of ammonia and oxide of copper, combined with ammonia.

IX. (a.) *EARTHS unite, by fusion, with the oxide of copper*, especially when aided by a fixed alkali.

(b.) *In coloring pottery and glass*, blues or greens are generally produced by oxide of copper, and if the oxide in glass is partially reduced the color is opake red.*

X. *THE SALTS* have little action on copper.

1. *Alum* dissolves a portion.

2. *Nitre*, at ignition, is sometimes used to oxidate copper for the preparation of enamels; the oxide, thus prepared, fuses readily into a brown glass.†

3. *Muriate of ammonia*, heated with copper filings, *evolves hydrogen*, and the gas ammonia and some of the copper or its oxide rise in sublimation.‡

4. *The chlorate of potassa burns copper* by the contact of an ignited body.

XI. *ALLOYS*.—*The alloys of copper are more numerous, and more important than those of any other metal*; of many of them, the composition is known, but there are various practical facts not always known to men of science, upon which their perfection and beauty may depend.§

1. *Molybdenum* with copper, produces a fusible compound of a metallic aspect.

2. *Manganese unites with copper*; the alloy is malleable; its color is red, but it becomes green by age.

3. *Arsenic has a strong affinity for copper*, but its volatility creates some difficulty in practice, as they must be united by fusion.

(a.) *They are placed in a well closed crucible*, and covered by salt to prevent oxidation.

(b.) Through the melted copper, the arsenic, either the metal or the white arsenic, with or without charcoal and pearl ashes, contained in a paper or in an inverted crucible, is thrust quite to the bottom.||

* The beautiful greens that are seen in the figures and foliage on the glazings of pottery are generally done with copper. (Bl. II. 642.) But oxide of chrome produces a richer green.

† Four. VI, 395.

‡ *Ens veneris* is muriate of ammonia with about 1-60 of green oxide of copper.

Celestial water is made by lime water, standing 10 or 12 hours in a copper basin with 2 parts of muriate of ammonia, or by the same mixture with a few copper filings, will produce the color in a glass vessel. Fourcroy.

§ The principal object is to obtain compounds that will not tarnish; that will not poison food; that will be more fusible and harder than copper; that will polish well, and that have colors resembling gold or silver, all of which are attained by different alloys of copper. Aikin's Dict.

|| Most of the arsenic escapes in white fumes, but by repeating the operation the copper is saturated; perhaps the following processes are better: white arsenic with oil, pearlash and charcoal powder is stratified with granulated copper in a covered crucible; or the latter with arsenical salt, calcined borax, charcoal dust and powdered glass; a gentle heat is applied at first, and then the melting heat of copper; or 10 parts of copper shreds with 1 of metallic arsenic, are melted in a covered cruci-

(c.) A white close grained, brittle metal is obtained; the arsenic is easily expelled by heat, and the copper becomes again malleable, but retains a little yellowness; this alloy, called tombac* is manufactured chiefly by the French.†

4. (a.) *Antimony easily unites with copper by fusion.*

(b.) With equal parts, the color is a beautiful violet, a solitary case among metals; texture lamellar, takes a fine polish, sp. gr. above the mean.‡

5. *Bismuth* fused with copper, in equal proportions gives an alloy of a pale red or reddish white color, its sp. gr. is exactly the mean of the two.

6. *Zinc, by fusion, unites readily with copper and forms brass and several other important compounds.*

Brass.

(a.) *Formed, directly, by melting 2 parts of copper and 1 of metallic zinc, or 4 of copper with 1 of zinc.* The copper, requiring an intense heat for fusion, is melted first and the zinc is added, the surface being covered with charcoal; much of the latter is burned with a brilliant white and blue flame, and the premises are filled with floating oxide of zinc, resembling tufts of carded cotton.§

(b.) *More economically; copper* 2 parts, divided into globules by pouring it when melted, through an iron cullender into water,|| 3 of roasted and pulverised *calamine*, with twice the volume of charcoal powder; they are ignited from eight to twelve hours. *The zinc, reduced by the carbon, would be vaporized and lost, but affinity unites it to the copper¶ to form brass;* the results of several processes are melted together and poured out upon large tables of granite furnished with a rim or border, and having a folding leaf also of granite, open-

ble, and in all cases the alloy must be poured out as soon as melted, or the arsenic will exhale.—Gray.

* Tombac is sometimes only brass and tin, or brass and arsenic.

† To equal parts of arsenic and copper, 1-16 of silver is sometimes added, as also tin, zinc or bismuth, and other metals, for utensils and trinkets.

‡ Old name *Regulus of Venus*.

§ This is the usual method of making brass in the United States; the crucibles are the black lead melting pots, and they are heated in a wind furnace; in Europe calamine and charcoal are sometimes added to copper and zinc; proportions, copper shot 54, divided zinc 27, calamine 10 and 1 bushel of ground charcoal.

|| Throwing in but little, at a time, on account of the dangerous explosions produced with water by this metal.

¶ Powdered calamine and charcoal, equal weights, mixed with clay, are rammed into a crucible, and two thirds as much copper as calamine are placed on the top and covered with charcoal; the zinc, from its volatility, leaves the foreign metals below finds the copper above, and forms brass which subsides and rests upon the clay.—Cramer, quoted by Ure, (*Dict.* p. 869.)

It appears that blende (sulphuret of zinc,) can be substituted for calamine (oxide or carbonate) in forming brass; roasting expels only a part of the sulphur, and probably the carbon flies away with the rest in the form of carburet of sulphur.—Thénard.

ing by hinges, in the manner of the common card tables; it is thus formed into plates.*

(c.) *Brass has nearly the color and beauty of gold; it is malleable* being easily beaten into leaves called Dutch metal; they are $\frac{1}{8}$ of an inch thick, about five times as thick as gold leaf, and they afford a cheap substitute for gilding, but are liable to tarnish; *ductile*, being drawn into wire, and it is worked with great facility in the lathe;† sp. gr. from 7.82 to 8.44; about $\frac{1}{8}$ greater than the mean of the two metals; not so good a conductor of heat as copper: brass is brittle when hot; when strongly heated, it loses its zinc, which burns at the surface. There are many varieties of this alloy.

(d.) *Pinchbeck*—Prince's or Prince Rupert's metal contains 3 or 4 parts of copper to 1 of zinc, (Bl. II. 646,) and some manufacturers add much more copper, even as much as 11 or 12 parts to 1 of zinc, when the color is almost that of gold; it is then often called *tombac*. The pinchbeck is used principally for trinkets and toys, intended to resemble gold.

(e.) *The Bath metal*, or similar, is composed of equal parts of zinc and copper,‡ 9 zinc to 32 brass, (Gray.) A compound of 5 parts of zinc to 8 of brass, forms a pale almost white metal called *platina*, and much used for making buttons at Birmingham.§

7. *Tin easily unites to copper*; the latter becomes more fusible, less liable to corrosion, harder, denser and more sonorous; a little tin makes copper very brittle, while the two metals are remarkably malleable and soft.

* My own observations (1805,) at a manufactory at Bristol, England; the plates thus formed are rolled out and drawn into wire to be used chiefly in the manufacture of pins, which are brass wire covered with tin. The Dutch brass is made in a similar way. It is composed of copper, 4 parts, and zinc, 1.

† Some kinds of brass work best under the hammer, some with the lathe. Mr. Chaudet (Ann. de Ch. et de Ph. Vol. V. p. 321,) found, on analysis, that the latter contained lead: the proportions of the constituents, in two specimens were, in one copper, 61.59; zinc, 35.30; lead, 2.86; tin, .25; and in the other copper, 66.80; zinc, 31.80; lead, 2.15; tin, .25. A specimen of the former gave copper, 70.10; zinc, 20.90; tin, a trace; and on adding the lead to the latter, it became capable of working well in the lathe. The alloy of zinc and lead should be formed first, and that with the copper last.

‡ It has a rich yellow color and is very soft and malleable; if a little iron or steel is added, the mixture proves as malleable when heated as iron, whereas brass, when heated, is brittle; when cold it is as strong as iron.

§ The manufacture of brass has been practised from remote ages. The ancients denoted brass by the name *orichalcum*; their *as* and *Χαλκος* were copper or rather *bronze*; Dr. Watson, Manch. Trans. Vol. II. p. 47. "The ancients in a degree, confounded copper, brass, and bronze. Brass was, in their view, only a more valuable kind of copper, and they often used the word *as* to denote either. Thom. Vol. I. p. 203, note. Brass is made into many ornamental and useful forms, and science is much indebted to this alloy for elegant and accurate instruments. Solder for brass is made by adding from 1 oz. to 6 ounces of heated zinc to a pound of melted brass. A softer solder is made by 1 part of tin to 6 of melted brass, and then 1 part of heated zinc; the solder is stirred and granulated by passing it through a birch broom into water; hard solder for copper, 8 brass and 1 zinc; a softer, from 3 to 16 lbs. copper, to 1 of zinc; still softer, 2 lbs. tin and 1 of lead. (Gray.) The white copper of the Chinese is composed of 40.4 copper 25.4 zinc, 31.6 nickel, and 2.1 iron—*Fyfe*.

The alloys with tin are of great importance ; they are

BELL METAL—CANNON METAL—BRONZE—METAL FOR MIRRORS
and a COATING FOR THE INTERIOR OF COPPER VESSELS.

Sp. gr. greater than the mean—it is at the maximum with 100 copper to 16 tin, being then 8.87 ; sp. gr. of equal parts is 8.79, but it ought by calculation to be 8.*

(a.) *Bell metal* is usually composed of copper 3 and tin 1 (which gives the most sonorous composition that has sufficient strength,) or copper 78 and tin 22 ; the tin is usually from $\frac{1}{16}$ to $\frac{1}{8}$; brass and zinc are added in some instances, also antimony and a little silver in some of the finer bells ; the popular impression is that silver improves the sound.† Bell metal is of a *whitish gray* color, sp. gr.‡ greater than the mean, *grain hard and close*, and difficult to be touched by the file, it is very elastic and sonorous, brittle if cooled slowly, if suddenly, malleable to a degree.§

(b.) *Metal of the Gong* ; this instrument of music, called also *tam-tam*, has, in modern times, been brought from China ;|| it is a broad flat disk slightly turned up at the border and bears marks of having been beaten by the hammer ;¶ when struck, it roars rather than rings, and with such rapid vibrations, as almost to overpower the ear, but the sounds, although diminishing, continue a long time. Its composition is 80 copper, 20 tin.—*Thénard*. That of ancient trumpet metal which had been hammered, was 1 part tin, to $7\frac{1}{2}$ copper.—*Pearson*.

(c.) *Bronze for Statues—metal for cannon*, (commonly called brass cannon,) and (anciently) *cutting instruments*, as sword blades, spear heads, &c. differ from bell metal, only in having a smaller proportion of tin. They contain, in general from $\frac{1}{8}$ to $\frac{1}{12}$ of tin.

This alloy is brittle, yellow, heavier than copper much more tenacious and less liable to alteration from the air.**—*Th. I. 176*.

* The fusion of the two metals must be long continued, with constant stirring, otherwise the tin rises and the copper sinks, and a very unequal mixture takes place. (*Th. I. 175*.) † Some have held the contrary opinion.

‡ Composition of English bells—copper 80 ; tin 10.1 ; zinc 5.6 ; lead 4.3. *Thom*. Clock bells contain a little more tin than common bells.

§ Most of the tin may be separated by pouring water upon the alloy in fusion, the tin is oxidated by the water, and forms a slag on the surface. (For other modes see *Four. VI. 360*.)

|| Similar instruments are known in Turkey. A large and fine gong is in possession of Mr. D. Wadsworth, of Hartford, Conn.

¶ Mr. d'Arcet discovered that although the alloys of copper and tin are more or less brittle when cooled slowly, after being ignited, they become malleable if plunged when red hot, into cold water. It follows therefore that the gong is first cast, then hammered into the desired form and then heated again to the necessary degree and cooled slowly to impart the temper proper for the desired sound. It is curious that while neither tin nor copper can be tempered by any treatment, the alloy possesses this property, but it is unlike the only other metal that can be tempered, namely, steel, for this is rendered brittle and hard by being ignited and plunged into cold water.

** The cannon metal at Woolwich, England is composed of 100 copper and 8 to 12 of tin, and is slightly malleable ; such cannon are less liable to rust than those of iron, and from their elasticity, they give a much sharper report, and are more prone to deafen the artillery men. They are more liable to heat and burn out at the

(d.) *Speculum metal*, is composed of 2 or 3 parts of tin* to 1 of copper; a little arsenic, brass and silver are occasionally added; also antimony and bismuth, but the essential things are tin, and copper.† It is a stiff, hard, steel-gray compound—little alterable by the air and susceptible of a fine polish.‡

(e.) *Copper vessels are tinned to render them safe for domestic use.*§ The metal is scraped clean, heated and rubbed with muriate of ammonia, and pitch or resin—a piece of tin is then applied by a folded cloth all over the inside, and the copper, which is kept hot enough to melt the tin, assumes a silvery whiteness.||

8. *Lead alloys very readily with copper*; with the lead in excess, the alloy is grey, when cold tolerably ductile, but brittle when hot, because the lead melts and runs out, leaving the copper porous; silver is in this manner extracted from copper ores, by the process of eliquation. An alloy of 100 lead to 20 or 25 of copper, is used for large printer's types. Roman pot metal was composed of 100 copper, 2 lead, and 2 tin, many ancient Grecian and Sicilian coins had a similar composition.

XII. NATURAL HISTORY.—*Copper is found native; as an oxide; a sulphuret, pure and mixed, and in the saline condition.* The ores of copper are fine subjects of mineralogical description, which would be inappropriate to the nature of this work.

1. *The native copper¶ needs only to be melted, and the oxides and the carbonates, are reduced with great ease, nothing more being necessary than to heat them with charcoal in a furnace.*

touch hole; there is in the tower of London a mortar of the largest size, which was spoiled in this way, at the siege of Namur. Bronze metal for statues, varies in the proportion of the metals. Pliny mentions copper 15 and 1 part of an alloy of equal parts of lead and tin; instead of the lead, modern founders add brass. The ancient cutting instruments contained generally about 1-9 or 1-10 of tin, sometimes, 1-6; they had sufficient strength, and could be brought to a good edge and were the best possible substitute for iron. Ancient culinary utensils had a similar composition. The copper coins or medals of the ancients were rather bronze than copper; the finest medals contain from 8 to 12 per cent of tin.

* Sometimes nearly half is tin.

† An ancient mirror contained copper 62, tin 32, and lead 8, the latter probably from impurity in the tin. (Klaproth.) Sir Isaac Newton's specula were composed of 6 copper, 2 tin, and 1 arsenic.

‡ Tutenag is a hard, tough and ductile white alloy of copper, zinc and iron, when polished, resembling silver in color and lustre. The Chinese Petong (or packfong?) is another white fine malleable alloy whose composition is not exactly known, except that it contains some silver.

§ The protection is important but not perfect; the tin should contain no lead, and food and especially acids should never be suffered to stand in such vessels.

|| The film of tin which adheres to the copper is extremely thin. Bayen found that a *steu-pan* 9 inches in diameter, and 3 inches 3 lines in depth, acquired, by the process of tinning, only 21 grains in weight. The coating cannot be made thicker, for, if more tin be applied, it will not adhere, but will run down to the bottom of the vessel. It is said that the French now use a compound of 8 parts of tin, with 1 of iron turnings, or nails, melted in a crucible under salt or pounded glass.

¶ Beautiful native copper has been found near New Haven, Conn. Am. Jour. Vol. I. p. 65; near Lake Superior, and in many places in that region.—*Id.* Vol. III. p. 201.

2. *The sulphurets are by far the most important ores*, because they are the most abundant; the gray ores are essentially sulphurets of copper, but the yellow* copper ores are sulphurets of copper and iron.

XIII. **EXTRACTION.**—*The extraction of the copper from the sulphurets is a tedious and troublesome process*, involving many details, for an account of which there is not room in this work.† In general, it may be said, that as much of the sulphur as possible is expelled by numerous roastings, with moderate fire, and the ore is afterwards melted, in contact with flame or burning fuel, to extract its oxygen. If silver is suspected to be present, 3 parts of lead are added to 1 of copper, and melted with it into cakes, which are placed on bars in the upper part of the furnace, inclined to each other so as to make a sort of groove, where they meet and are gradually heated; the lead melts long before the copper and takes along with it the silver, and if it be rich in silver this is afterwards extracted from it by cupellation. The copper is left in the form of a spongy mass; it is again melted; its surface is made to congeal by throwing hot water upon it with a broom; the congealed cake is lifted off, and is called *roseate* or *rose copper*, or it is run into plates and slabs.

The poorest sulphureous ores are converted into sulphate of copper, by burning, moistening and suffering them to undergo sulphatization, (sometimes this happens spontaneously;) the salt is then extracted by lixiviation and crystallized. Or, pieces of iron are introduced into the solution, or into that which runs from the mines, and the copper is thus precipitated; it is called *copper of cementation* and is collected and melted into masses.

XIV. **MISCELLANEOUS.**—It is scarcely necessary to expatiate on the utility of a metal which, in importance, is next after iron; to the ancients it was as indispensable as iron to the moderns. *Copper, being poisonous, must be excluded from food.* If *copper vessels* are *clean and bright*, hastily used, kept full and covered while in use, and emptied immediately after, it is found by the experience of confectioners, and of families in preparing preserves, &c. that they *do not impart any noxious qualities*.‡ But if aliments be suffered to

* The yellow ores are the great object of research in Cornwall, England, where, among the vast piles that were lying by the mines, I scarcely saw any of the gray. The yellow and gray sulphurets are found in this country, in New Jersey, in Connecticut, &c.

† See Black's Lectures, II. 649, Fourcroy, VI. 334, Aikins' Dict. Vol. I, p. 324, Thénard's Chem. 5th ed. Vol. III, p. 529, and Gray's Op. Chem. p. 635.

‡ Metallic copper does not appear to act on the system, except mechanically; copper filings were formerly given, in drachm doses, for rheumatism, and copper has remained for years in the alimentary canal, without fatal consequences.—Coxe's Dispensatory, 287.

stand in them, in the air, the metal is oxidized, and a portion of it is dissolved. The aromatic and unctuous oils easily dissolve oxide of copper and acquire a green tinge, and unctuous oils are frequently present in our aliments. They act much more rapidly if rancid, for their rancidity is owing to the absorption of oxygen and this aids the oxidation of the copper. In the tallow of common candles, a little verdigris is added to improve the color, and the fine green of pickles, sweetmeats, &c. is sometimes said to be owing to the same cause. The tests for the discovery of copper have been already pointed out, and perhaps precipitation by clean iron and the blue color by ammonia are the best. *Sugar has been found to be a powerful antidote to copper.* Hence syrup should be swallowed copiously, if verdigris or any other preparation of copper has been too freely taken.* It is not known in what manner sugar acts; probably, however, by neutralizing the copper, for a solution of 1 oz. of white sugar and 10 grs. of verdigris in 1 oz. of water, although of a green color, was not affected by prussiate of potassa, ammonia or the hydro-sulphurets.

XV. POLARITY.—*Electro-positive*; appears in beautiful red filaments and scales upon the negative wire of the galvanic series, when immersed in a cupreous solution, the battery being in activity.

SEC. XXXII. NICKEL.†

I. HISTORY.—Announced by Cronstedt from 1751 to 1754, as existing in kupfernickel, (false copper) which is arsenical nickel, mixed with sulphuretted cobalt and iron, and was supposed by most chemists to be an alloy of copper and iron. Bergmann, (1775,) proved that it was a distinct metal.‡ Since that time it has been investigated by many chemists.

II. EXTRACTION.—Its ores are kupfernickel and nickel ochre or oxide.§ The processes for extracting nickel, have been considerably varied; the following selection embraces the most important steps.

1. *The common process.*—Roast the kupfernickel to expel sulphur and arsenic; it is then mixed with 2 parts of black flux, covered

* Ure's Dictionary.

† Found at Chatham, Conn., along with the ore of cobalt. These two metals are associated usually in the mines; but they are no longer, as formerly, associated or identified in a chemical arrangement, the purified nickel being found to possess properties that assimilate it to the noble metals.

‡ Bergmann, Vol. II, p. 231; Ann de Ch. Vol. LXII, pp. 107, 164; Vol. LV, p. 137; Vol. LX, p. 260; Vol. LXIX; Vol. LXXXVIII, p. 133; Jour. de Phys. Vol. LVIII, p. 64; Ann de Ch. et de Ph. Vol. IX, p. 267; Vol. XXV and XXXIII; Nicholson's Jour. Vol. XII.

§ For the analysis, see Accum's Analytical Mineralogy and Alkin's Dict. Vol. II, p. 125.

with common salt, heated in a forge furnace and an impure metallic button is obtained.

2. *To remove the impurities.*—Dissolve the common regulus (metallic nickel of commerce,) in boiling nitric acid; the arsenic will be changed into arsenic acid, and nitrate of lead will precipitate the arsenic; evaporate by a very gentle heat, but not to dryness; add alcohol which takes the water and precipitates every salt but nitrate of nickel; the alcohol of the decanted solution is evaporated; the nitrate of nickel is redissolved in water, and the oxide thrown down by potassa; lastly, the oxide is well dried and reduced in a crucible lined with lamp black.

3. *Process of Dr. Thomson, suggested by Dr. Wollaston.*

Add sulphuric acid to the pulverized speiss,* of commerce, (composed chiefly of arsenic and nickel,) and, at intervals, nitric acid, about one fourth part; there results a green solution and after a subsidence of several hours, arsenic remains. Decant and evaporate the green liquid and obtain crystals of sulphate of nickel; a farther evaporation gives a crust of arseniate and sulphate; dissolve this in water and pass through it sulphuretted hydrogen, till precipitation ceases; filter again, evaporate and obtain more of the apple green matter; dissolve again and it will become opaque owing to precipitation of arsenious acid; filter and again evaporate and obtain pure sulphate of nickel, and for greater security the entire sulphate obtained, may be dissolved, filtered, evaporated and crystallized anew. This sulphate being again dissolved, is decomposed by carbonate of soda and the resulting carbonate, made into balls with oil and surrounded with charcoal in a crucible, is heated for two hours, in a melting furnace. This process always gave Dr. Thomson a button of pure nickel.†

The oxalate, prepared in the same way as oxalate of cobalt, (see this Vol. p. 202,) and being heated in close vessels, yields metallic nickel in the form of a black powder, or it is easily reduced by passing hydrogen gas over its oxide, laid in a porcelain tube across a furnace.

III. THE METAL.—*Properties.*

(a.) When pure,‡ *color intermediate between that of silver and tin; lustre, when polished, very high, and between that of steel and platinum.*

* A substance remaining at the bottom of the crucibles, in which cobalt is prepared.

† Ann. Phil. XIV, p. 144 and Henry, II, 170. See also Nich. Jour. Vol. XII, and Ann de Chím. Vols. LXIX and LXXVIII; Ann. Philos. N. S. III, 201 and VII, 395; Ann de Ch. et de Phy. Vol. IX.

‡ As commonly seen it is yellowish white, and brittle. It is not easy to obtain pure metallic nickel even in London and Paris; I have repeatedly sent to those cities without obtaining it. I have now a fine piece brought from Germany, and presented by the kindness of Mr. W. C. Woodbridge.

(b.) *Malleable*, can be forged into bars when hot, and hammered into plates when cold. Sp. gr. when cast, is 8.402, forged 8.666.* *Ductile*; it can be drawn into very fine wire; it becomes oxidized if we attempt to solder it.

(c.) *Less fusible than iron*; infusible as manganese. In a covered crucible, some of it is volatilized, and appears in drops on the cover of the crucible.

(d.) *Is attracted by the magnet* almost as powerfully as iron, and becomes itself a magnet by touching, hammering, &c. The magnetism is the stronger, the purer the metal is; a needle made of it, and suspended, points to the north as freely as one of iron, but its magnetic power is only $\frac{1}{4}$ as great.† This was supposed to be owing to iron, but is now believed to be a property of this metal. As it does not rust, it has a very great superiority over steel, for this purpose.

(e.) *Arsenic impairs or destroys the magnetic virtue.*

IV. RELATION TO OXYGEN.

(a.) *Oxidized with extreme difficulty* by heat and air; endures their action almost as well as gold, silver and platinum, but by continued heat in the air it becomes, at last, a dark brown oxide, still magnetic.

It burns brilliantly under the compound blowpipe.

(b.) *Nitre, with heat, converts it into an oxide.*

(c.) *At a high heat its oxides are said to be reducible by heat alone,*‡ and as it is little tarnished by heat and air, and is eminently malleable and ductile; Richter, and others call it a perfect or noble metal.

(d.) The green hydrated oxide of nickel exposed to a red heat or to chlorine, becomes a black oxide.

(e.) *Authors are not agreed as to the equivalent of nickel*; according to Dr. Thomson, it is 26; Lassaigne, 40; Phillips, 29; Brande 30; it is therefore evident that the subject needs farther investigation.

(f.) *Protoxide*.—Dr. Turner admits 26 as the equivalent of this metal, and its protoxide with 1 equiv. of oxygen, is of course 34. It is formed by igniting the carbonate, oxalate, or nitrate of nickel in an open vessel and is then ash gray, but after ignition it becomes dull olive green, or brown; it is not magnetic; the pure alkalies throw it down as a pale green hydrate; ammonia and its carbonate in excess redissolve it; hydro-sulphurets precipitate it black, but sulphuretted

* By hammering it can be increased to nearly 9.—8.932.

† Authors differ on this point; see magnetism under general properties of metals; if nickel not quite pure, has its magnetic power expressed by 36, that of iron will be 55, and that of cobalt 25. Lampadius in Thomson's Ann. Vol. V. p. 62.

‡ Thénard suggests that possibly its reduction may have been produced by carburized hydrogen making its way through the cracks of the crucible, and says that he had in vain attempted to reduce it in a well closed crucible.

hydrogen produces no precipitate unless it is neutral or united with a weak acid.* It is a strong base uniting readily with acids, and by long ignition in a charcoal crucible, it loses 22.5 out of 100.

(g.) The peroxide is supposed to consist of 1 equiv. of nickel 26 + $1\frac{1}{2}$ of oxygen 12 = 38. Formed by passing chlorine gas through water in which the hydrated protoxide is suspended, it does not unite with acids, is decomposed at ignition, giving out oxygen gas and with hot muriatic acid evolves chlorine gas.—*Turner*.

V. COMBUSTIBLES.

1. Sulphur.

(a.) *The sulphuret of nickel is formed by melting the metal and sulphur together*, or by precipitating the salts of nickel by hydro-sulphurets.

(b.) *The compound is gray or yellow with a metallic lustre; it is hard, brittle, has a close grain, and burns when heated in contact with the air.*†

(c.) *There are two sulphurets*, one with 34, and the other with 43.5 per cent. of sulphur.—*Davy*. In the bi-sulphuret, the magnetic property is lost.

2. *Phosphorus*.—The phosphuret of nickel is formed in the usual way, but it appears to possess no peculiar properties, being, in appearance, white and metallic, and presenting a congeries of prisms.

3. *Carbon* combines with nickel as is found when it is used in reducing its oxide.—*Berthier*.

The compound resembles iodine or micaceous iron.

VI. RELATION TO ACIDS.

The salts of nickel are green and crystallizable; the acids unite only with the protoxide, and the taste of the salts is sweetish.

1. *Sulphuric acid; action weak*, unless aided by a boiling heat, or by small portions of nitric acid, when some nickel is dissolved; the superfluous acid being driven off by heat, a part of the remaining mass is soluble in water, and by evaporation, gives rhomboidal octahedra or rhombic or square prisms of a light emerald green; the water has the same color and a similar salt is obtained by dissolving oxide of nickel in this acid; taste sweetish and astringent; becomes greenish white by moderate ignition; composition, acid 29.2, protoxide 24.8, water 46. The sulphate of nickel exists in small quantities in the waters of some mines.

2. *Nitric acid; the action is rapid* on both the metal and oxide; most on the impure metal; the pure requires the aid of heat; solu-

* *Turner*, 3d. Am. Ed., p. 346.

† *Berthier* (Ann. de Ch. et de Ph. Vol. XXXIII. p. 57.) obtained sulphuret of nickel by heating arsenical nickel, carbonate of soda and sulphur together; it was mixed however with sulphuret of sodium and sulphuret of arsenic.

The sulphuret according to him resembles exactly iron pyrites.

tion rich green; gives rhomboidal crystals, which are deliquescent, and in a warm air ultimately crumble into a greenish white powder; this salt is partially decomposed by heat.

3. *Muriatic acid*; scarcely any action; it is even boiled on reguline nickel, to render it clean; dissolves the oxide easily and affords irregular crystals, first deliquescent and then efflorescent.

4. *Nitro-muriatic acid*, dissolves nickel with facility, and forms a muriate or a mixed muriate and nitrate.

VII. CHLORINE.

Nickel heated in chlorine gas, forms an olive colored compound, and the evaporated and heated muriate affords brilliant yellow scales; both being, probably the bi-chloride.—H.

VIII. IODINE.—By precipitating any salt of nickel with hydriodate of potassa, an iodide of the metal is formed; it is green and insoluble.—Id.

Decomposition of salts of nickel.

(a.) *Alkalies precipitate the hydrated oxide*, more or less free from the acid; they (especially ammonia in excess,) re-dissolve the hydrated oxide.

(b.) *Carbonated alkalies throw down a carbonate of nickel* of a delicate apple green; it is changed by heat to dark gray, and ultimately becomes attractable by the magnet.

(c.) *Ammonia gives a green precipitate, resolvable in more of the alkali, becoming of a beautiful sky blue*, and in a hour or two amethyst red and violet; these colors are converted again to green, by an acid, and again to blue and violet, by ammonia; if the color is permanent, copper is to be suspected.

(d.) *The nickel is precipitated immediately from this ammoniacal solution, by either of the caustic fixed alkalies*; cobalt is but slowly thrown down and the precipitate is reddish; this affords a means of separating these metals.

(e.) *Metals do not precipitate pure nickel*; from the impure, they precipitate arsenic and iron—and the green color of the solution is thus improved.

(f.) *Hydro sulphurets of alkalies give a black precipitate*, with salts of nickel; sulphuretted hydrogen produces no effect.

(g.) *Prussiate of potassa gives a greenish* (according to my experience, an almost white slightly tinged with green,) *precipitate*; with copper, a brown.

(h.) *Tincture of galls, produces no effect.*

(i.) *Alkaline sulphurets dissolve nickel.*

(j.) Nickel is not precipitated by iron, or zinc; by sulphur or phosphorus.

IX. ALLOYS.

1. *Gold*; with 20 grs. to 1 oz. of nickel, an alloy of a brass color is formed, coarse grained, and brittle.

2. *Silver*; nearly equal proportions, no important change in ductility or color.

3. *Copper*; ductility and magnetic virtue impaired; the latter not destroyed.

4. *Tin*; a white brittle compound.

5. *Arsenic readily combines with nickel*; alloy brittle and fusible, giving a garlic odor by heat.

6. *Iron unites with nickel in all proportions*; if nickel prevails, the metal is white and the ductility and magnetism are equal to that of iron; it does not amalgamate with mercury.

This alloy is constantly found in meteoric iron, and this is supposed to be the reason why it is so little prone to rust.* That of Baffin's bay, contained 3 pr. ct. that of Siberia 16, that of Louisiana, 9.6, that of Virginia, 6.10. In examining such bodies I have made use of the hydro-sulphuret of ammonia, to precipitate the nickel from the nitric solution, the iron being first removed by ammonia, and the absence of it proved by tincture of galls, and by prussiate of potassa, the latter failing to give a blue, and yielding only a white precipitate.

Oxide of nickel combines by fusion with vitrifiable matter, and gives a hyacinthine color, also a similar color to borax, and phosphate of soda.

Pure nickel† being *dear and rare*, and the processes for obtaining it pure being very troublesome, it is entirely unknown in society, and almost so in the arts. It would be an interesting metal, if it could be easily and cheaply obtained.

SEC. XXXIII.—MERCURY.‡—QUICKSILVER.

I. NAME AND HISTORY.—*The Latin hydrargyrum* is from the Greek *ὕδωρ*, water, and *αργυρον*, silver, in allusion evidently to its fluidity and silvery appearance. The name quicksilver carries the same allusion, and the alchemists appear to have regarded this metal as silver in a fluid state, quickened by some inherent volatile principle, which they hoped either to fix or expel.

Known to the ancients, especially to the Greeks and Romans who employed it in gilding and in the extraction of the precious metals as is done at the present day.

* Large masses of meteoric iron in Siberia, Peru, Louisiana, &c. have lain in the open air apparently from age to age without rusting, or only superficially; if it should be found that nickel will effectually protect iron from rusting, the fact might prove of the greatest practical consequence, in the construction of many instruments for science and the arts.

† Common nickel is much used in the arts for alloys, one of which resembling silver is imported from Germany in bars and wire, and used in making the new musical instruments called mouth harmonicas.—G. C.

‡ This is the alchemical name after the planet mercury, and it is singular that this metal is the only one that retains the name imposed by the alchemists.

Regarded formerly as an imperfect metal because it was not solid and of course not malleable, and even the brittle metals were called semi-metals. This distinction is now banished, and if it had ever any foundation, with respect to other metals, it has none in the case of mercury, which has been frozen repeatedly, and while solid, is malleable; when fractured, it shews a crystalline structure.

II. PROPERTIES.

(a.) *Fluid, white, brilliant as polished silver*; a clear white glass tube filled with it cannot be distinguished by the eye from burnished silver; the clean surface of a vessel of mercury, especially in a face of some square feet,* is a most splendid and beautiful mirror.†

(b.) *The only metal that is fluid at common temperatures.*‡

(c.) *Not essentially fluid* as once supposed; owes this state entirely to heat; *can be frozen* at -39° or -40° , by nitric acid and snow; or, *muriate of lime and snow*; or, potassa and snow; or, by evaporation of condensed sulphurous§ acid; or, of sulphuret of carbon, from a glass ball filled with mercury and exposed to air pump exhaustion, (Vol. I. pp. 316, 364.) in the three first cases it is the abstraction of the heat necessary to fluidity, and in the two last to the state of vapor, that produces the effect.|| First obtained frozen in 1736, at Yakutsk, in Siberia.

* As in the mercurial pneumatic cisterns in laboratories.

† Every one knows that our common mirrors are coated with an amalgam of tin and mercury, sometimes with the addition of bismuth.

‡ If potassium and sodium were not more liable to be oxidized than mercury, they would, in the open air, exhibit the effect of varying temperature; at a medium heat they are plastic solids; at a temperature not above extreme summer heat, potassium would be fluid, and it would be generally so at the equator, and sodium would be fluid with double the same degree of heat; lead, and tin, and gold, are soft metals, and form a transition from potassium and sodium to zinc, silver, iron, &c. and thus the aggregation of the metal evidently depends upon heat.

§ With 1 dr. of which, thrown in a jet upon the metal, Dr. Torrey informs me he has, in a few seconds, frozen 100 grs. of mercury.

|| I have frozen mercury in presence of a class, with muriate of lime and snow, and have seen it done elsewhere, but it requires too much attention to be in general, a very good class experiment. It will of course be done in the winter, and when it is very cold weather. Two parts of dry pulverized muriate of lime, and one of snow (fresh fallen and very dry,) are placed in separate vessels and cooled to zero, by immersion in a mixture of 2 parts of common salt, and 1 of snow; the mercury contained in a small tube or ball should be cooled in the same manner; the muriate of lime and snow are then promptly mingled in a vessel of pottery, which has itself been cooled by similar means, and three hundred or four hundred grains of mercury, in three or four quarts of the freezing mixture, will be frozen in a few minutes. See Dr. Blagden's account, Phil. Trans. Vol. LXXXIII. Messrs. Allen and Pepys froze 56 lbs. of mercury at once, (Tilloch's Phil. Mag., Vol. III, p. 76,) and the cold condensed the air of the room into a dense cloud. It is commonly said that the muriate of lime should be crystallized; on account of the water of crystallization which increases its power, but this is not easy on account of its deliquescence, and it answers very well in dry powder as I have found, having kept it unchanged for years. See this volume, p. 63, note. Mercury was first frozen by the Russian academicians by a very intense natural cold, increased by a mixture of fuming nitrous acid and

(d.) *When the mercury is partly congealed, if the fluid part be poured out, octahedral crystals are obtained.*

(e.) *Frozen mercury may be cut with a knife; it flattens under the hammer, and is therefore malleable; I have observed, that in pulling a frozen mass with pincers, it extends and is therefore ductile; but it falls rapidly in drops during these operations which are but momentary.* In attempting to bend it, it breaks. The touch of frozen mercury whitens and disorganises the skin like a burn, and with a similar sensation.*

(f.) *By freezing, the sp. gr. of mercury which at 47° Fahr. is 13.545† is increased to 15.612: about $\frac{1}{4}$: frozen mercury sinks in the fluid metal.*

(g.) *Mercury is perfectly mobile, and is the most beautiful of permanent fluids; if clean and pure it does not soil the hands or glass vessels;‡ from its great weight it affords the most perfect means of demonstrating the statical and moving power of fluids; it is indispensable in the construction of the barometer, and almost so in that of the thermometer.*

(h.) *Its particles attract each other; in glass vessels its surface is convex, receding from the sides; but in most metallic vessels, owing to the attraction, its surface becomes concave and forms a ring as water does in glass.||*

snow; when the mercury ceased to sink in their thermometers, they found on breaking the bulbs, that it was congealed. Professor Pallas, at Krasnojacks, in Siberia, A. D. 1773, caused mercury to congeal by a natural cold of $-55\ 1.2^{\circ}$ Fahr. and Mr. Hutchins observed the same fact at Hudson's Bay, in 1775: also, Mr. Bricker at Rotterdam, (1776.) It readily freezes in the natural cold of the polar winter, as observed by the late northern navigators and travellers; hence the necessity of carrying alcoholic thermometers.

* If the air, the instruments and the metal could be kept at -40° , these operations might be continued; but animal temperature and respiration would eventually melt the frozen metal.

† 13.568, Thénard; a cubic foot weighs 13,568 oz. avoird.; a cubic foot of water at 55° Fahr. weighs 998.74 oz. avoird., and in freezing, water expands about 1-8 or 1-9, and yet both fluids assume a crystalline arrangement.

‡ I have seen it in a quantity of 150 or 200 lbs. so contaminated by other metals by use as a mercurial cistern, that it adhered in films, covering the hands and vessels immersed in it.

|| In the falling barometer its surface is concave.—J. G.

If allowed to run through a fine rag or a capillary orifice, as by piercing a conical paper with a pin, and letting the mercury run through it, moving it at the same time briskly about, or by holding the finger on the mouth of the funnel containing the metal, which is then allowed to flow in a minute stream upon a large and clean glass plate, it forms itself into innumerable globules, which, if the mercury be pure, are always flattened spheroids, but with a clean and well defined outline: otherwise they adhere to the glass, and when pushed along, they become extended into a continued line. The workmen at the mines, who call this metal *quick*, are able to judge very well of its purity, by pouring it from one hand into the other.

It is said that impure quicksilver is sometimes obtained from the looking glass makers; it is of course alloyed by tin, and sometimes by bismuth and lead; it is cheaper than the pure, and is occasionally fraudulently manufactured into the blue pill and the blue ointment.—Gray.

(i.) *Imparts a peculiar taste*; perceived when it is rubbed upon the tongue, *but there is no smell* except from its vapor, which is slightly disagreeable.

(j.) *Does not sensibly evaporate at common temperatures*; yet Mr. Faraday found gold leaf whitened by hanging sometime in a vessel over mercury; minute drops of mercury also collect in time in the vacuum of the barometer,* looking like a mere film, but the magnifier discovers minute drops of mercury.†

(k.) With a little more than three times the heat of boiling water, mercury also boils, and is converted into a true vapor; *the boiling point has been variously stated*, 656°, (Crichton,) 662°,‡ (Petit and Dulong.) The vapor forms a white cloud in the air; if pure, the metal evaporates without residuum, and as it readily condenses, it forms "a white dew on the adjacent bodies, which is found by the microscope to consist of myriads of minute globules."—*Aikin*.

(l.) *Its vapor is expansive*, (Vol. I. p. 56. d.) and weighs nearly seven times (6.9760) as much as the same volume of common air.§

(m.) *The vapor is noxious*; Fourcroy says (Vol. V. p. 387,) that he has seen persons struck by it with asphyxia and paralysis.||

(n.) *Mercury is purified* by exposing a thin stratum of it to sulphuric acid 1 and water 3, with agitation; after 4 days the oxides are washed away, and the mercury is then rendered pure *by distillation*;¶ it may be done in an iron vessel or in an earthen or even glass retort; the fire must be moderate; the apparatus under a chimney, and a towel or cloth should be attached to the neck of the distilling vessel and should dip into water contained in any convenient receiver.**

* Especially if standing by a window in a warm room.

† It is said also that there is a phosphorescence perceived in this vacuum, but this is doubtless an electrical phenomenon, produced by the friction of the mercury upon the glass.

‡ And by a corrected thermometer, 680°.

§ Ann. de Ch. et de Ph. Vol. XXXIII. p. 353.

|| I have observed thermometer makers to run away when the glass ball bursts during the boiling of the mercury; I have often met with this occurrence, but have received no injury from it, nor from the vapor of the revived mercury when its fulminating preparation is exploded; it is proper however always to avoid the vapor of this metal; some persons are salivated by it.

¶ The contaminating metals are, usually, lead, bismuth or tin. Fourcroy says he has rarely found it to contain more than 4 or 5 per cent. of foreign metals.

** The alchemists were bent on *fixing* quicksilver, and they conceived that it contained a volatile principle, which being expelled, the silver would become solid. For this purpose, it was subjected to great heat, in closed iron globes, placed in hot furnaces, which ended, as might be supposed, in terrible explosions. Fourcroy relates, that in the house of the apothecary Geoffroy, in Paris, in 1732, they enclosed mercury in an iron box, surrounded by five others in succession, and the last was secured by very strong intersecting iron bars; the apparatus was then thrown into a well heated furnace, when, in due time, a loud and violent explosion projected the fragments, like those of bomb shells, with such force that they penetrated the walls of the building. These preposterous experiments are however interesting, as they

(o.) *Mercury, as a metal, is a good conductor of heat, and being also fluid, it so effectually embraces the hand plunged into it, that it produces often a decided sensation of cold, although the thermometer proves that it is of the same temperature as the surrounding objects.*

III. RELATION TO OXYGEN.—*Combustibility.*

(a.) *Thrown upon red hot coals, it evaporates with a crackling noise, produced by innumerable trifling explosions, but there is no appearance of combustion, and it is too volatile to be burned by the blowpipe.*

(b.) *The galvanic discharge, taken through it, from a charcoal point, produces, however, a vivid, greenish white flame; the mercury burns and is dissipated, and Dr. Hare caused a stream of mercury, flowing from a funnel, to burn splendidly on receiving the discharge from a powerful deflagrator.*

OXIDES.—*There are two, the black and the red.*

1. Protoxide or black oxide.

(a.) *Pure mercury, exposed to the air, scarcely undergoes any change, but by long agitation of the mercury of commerce, a part of it is converted into a gray powder;* it is however doubtful whether pure mercury is ever oxidized by the cold air.*

(b.) *By rubbing it with oils, unguents, gums, honey, manna, &c. it is minutely divided, so that the globules are no longer visible, even with the aid of a magnifier; in this state it is commonly regarded as black oxide of mercury; if so, it is of extremely easy reduction, as the globules reappear by heat and the sun's rays.†*

(c.) *Some chemists doubt the existence of a protoxide of mercury, distinct from a state of combination with acids, with which it is allowed that it exists in a saline condition.‡*

(d.) *Processes for the protoxide.—Briskly triturate calomel, in excess, with a hot solution of potassa or soda, edulcorate with cold*

prove that mercury can be converted into an elastic vapor, whose expansive efforts are as great as those of steam or of the gases from gunpowder.

* This was formerly effected by fastening strong vials, containing mercury, enclosed tight, with much air, to the wings of windmills, the arms of fulling mills or the spokes of coach wheels, and the agitation produced by their motion converted a part of it into the gray or black powder, called by Boerhaave, who first obtained it, *othlops per se*. He also distilled the same portion of mercury five hundred times, with no other change than the production of a little of the gray powder, which, by trituration, became again metallic mercury. Gay-Lussac (Ann. de Ch. et de Ph. Vol. I, p. 424, note,) doubts whether pure mercury is ever oxidized by the air.

† The blue pill and the most common mercurial ointments, contain mercury in this state. Mr. Carpenter, of Philadelphia, (Am. Jour. Vol. XII, p. 173,) contends that in the blue pill the mercury is merely divided and not oxidized, and Laugier (Cours de Chimie, Tom. II, p. 310,) says; "On est fondé à croire aujourd'hui que ce changement de couleur tient seulement à l'extrême division des parties du métal." This extreme division is, however, highly favorable to the combination of oxygen, and perhaps the middle opinion may be the more correct, namely, that a part of the metal is in the state of extreme division, and part in the state of oxide.

‡ See Ann. de Chim. et de Phys. Vol. I, p. 42.

water, dry in the cold and in darkness; or precipitate the oxide from the proto-nitrate by lime water. (H.)

(e.) *Properties of the precipitate.*—Color dark gray, almost black; insoluble in water; exists in the proto-nitrate of mercury; by pressure,* yields running mercury, mixed with the deutoxide, and then, by muriatic acid, forms corrosive sublimate, and leaves a portion of deutoxide.†

(f.) *Composition.*—Mercury, 1 equiv. 200+ oxygen, 1 equiv. 8 = 208, its equivalent.

2. *Deutoxide or peroxide.* This oxide is perfectly distinct and indubitable both in a combined, and in a separate state. There are two varieties known in commerce; the precipitate per se, and the red precipitate from the nitrate; they are essentially the same, and the difference as far as any exists, will be indicated immediately.

Process for the deutoxide.

1. *Red precipitate, per se.* Mercury placed in a vessel, shaped like a pear, or better perhaps a flat bodied retort with a slightly curved neck,‡ is heated nearly or quite to ebullition; the air has access and the metal rising in vapor, is condensed, and falls back into the vessel. In 10, 12, 15 or 20 days, a part of it is converted into a red oxide, which may again be heated in the open air, in a broad vessel§ to expel any running mercury.

2. (a) *Red precipitate from nitrate of mercury.* We anticipate so far as to mention the nitrate now; it will be named again with more precision in its proper place.

(b.) *The solution of the nitrate is evaporated to dryness, and exposed to a pretty strong heat, (about 600° F.)* in a porcelain cup or a retort; the nitric acid is decomposed, and expelled in red fumes and when they cease, the oxide will become of a beautiful red color.||

* Pressure may, and probably does, produce a decomposition, evolving metallic mercury and causing the production of peroxide, by the transfer of oxygen from a part of the protoxide.

† These are anticipations, which will be cleared up in the sequel of this section.

‡ It being necessary at once to oxygenize the mercurial vapor, and to prevent its escape, they employ glass matrasses with broad and thin bottoms, and tall necks, with a small orifice to admit the air and repress the vapor; sometimes a lateral orifice is preferred, and it is thought that a communication with oxygen gas would facilitate the result.

§ Lavoisier (see his Elements) placed mercury in a glass retort whose neck was curved upward so as to pass into a jar containing 50 cubic inches of common air, confined over mercury; heat was applied a little under ebullition, 7 or 8 cubic inches were absorbed, red oxide was formed, and nitrogen left in the jar; the red oxide was heated in another retort, and pure oxygen gas obtained, which, when added to the residuary nitrogen, again formed true atmospheric air.

|| Other particulars will be named under the nitrate; much practical nicety seems necessary in order to obtain a beautiful result.

Properties of the deutoxide, or red precipitate.

(a.) *Acrid, purgative, emetic, escharotic,* and poisonous.* By heat, not so high as to decompose it, forms a red sublimate.

(b.) *Rubbed with zinc or tin filings, it inflames them, and acts in a similar manner upon most combustible bodies.*

(c.) *Color scarlet or yellowish red; the precipitate per se is crimson, and the crystals are imperfect octahedra; the nitrous precipitate is of a more lively red and in crystalline scales; it is much the most acrid and both varieties are too much so, for internal use.*

(d.) *By ignition the mercury is revived, and very pure oxygen gas obtained;†* from the nitrous precipitate some nitrogen gas is expelled and a little corrosive sublimate rises, owing to muriatic acid,‡ either an impurity in the nitric acid, or added by design, to improve the color of the precipitate.

(e.) *Soluble in a small degree in water§ which acquires an acrid taste and turns syrup of violets green and is precipitated by sulphuretted hydrogen; it is said that red oxide is decomposed by the sun's light into oxygen gas and running mercury.||—Gusbourt.*

(f.) *It seems now agreed that the two red oxides are identical except that a little nitric acid adheres to the precipitate obtained from the nitrate and therefore a little nitrogen is obtained in its decomposition by heat.*

(g.) *Composition. Mercury, 1 equiv. 200 + 2 equiv. oxygen, 16 = 216, its equiv.* It has therefore exactly twice as much oxygen, as the protoxide whose equiv. is 208; 100 parts of mercury take 4 of oxygen, to become protoxide, and 8 to become peroxide.

IV. *WATER, when pure, has no action upon pure mercury, but if the mercury of commerce, which generally contains a little alloy of some other metal, is boiled with water, the latter becomes turbid, acquires a metallic taste, and the power of destroying worms and other insects.¶—Aikins.*

V. *COMBUSTIBLES.—Mercury unites only with phosphorus and sulphur.*

* Used by surgeons to remove fungous flesh.

† Holding a little mercurial vapor which might produce salivation if breathed immediately.

‡ In the proportion of a drachm, to a pound of nitric acid; some add common salt instead of muriatic acid.

§ When purified by copious washings, it is not soluble in water, and it is probable, that in ordinary cases, a little undecomposed nitrate is dissolved.—A. A. H.

|| I have kept specimens of both the precipitates, 28 years in glass vessels in a light place without the slightest change, not even a diminution of the brightness of the color.

¶ It is probably a galvano-chemical effect, produced partly by impurities in common water if that is used, or if distilled water is employed, it is owing to the conjoined effect of air, water and the metal; we may presume that in clean glass vessels, filled with pure water, and sealed from the air, mercury would not acquire any impregnation.

1. *Phosphorus—phosphuret.*—No union between phosphorus and metallic mercury, heated even for months, under water.

(a.) *Heat either of the oxides along with phosphorus*, (equal parts,) in a retort filled with hydrogen gas, or under water with frequent agitation; the oxide is reduced and a phosphuret is the result.

(b.) *Properties.*—*Black; easily cut with a knife; in the air, it exhales vapors of phosphorus.*

2. *Sulphur.—Sulphurets.*—*There are two*, the proto- and the deuto-sulphuret; *the black and the red*, although in some cases in which the proto-sulphuret was formerly supposed to be produced, there appears to be merely a mixture of the per- or deuto-sulphuret, (cinnabar,) and sulphur or mercury, or both. Of this description, (according to M. Guibourt,) is what was formerly called ethiops mineral; but Mr. Brande* says, that this compound, if properly prepared, does not whiten gold, when rubbed upon it, which proves that there is no free mercury.

1. *Proto- or black sulphuret.*

(a.) *Formed by rubbing*, vigorously, in a glass or porcelain mortar, 3 parts of *sulphur* and 1 of *mercury*; or *by adding mercury*, at intervals and with agitation, to its own weight of *melted sulphur*.†

(b.) *A proto-sulphuret is said to be formed by passing sulphuretted hydrogen gas through powdered calomel*, suspended in proto-nitrate of mercury, dissolved in water; but in both cases, mercury is obtained from it, by mere pressure,‡ and mercury and cinnabar by sublimation, (sulphurous acid and sulphuretted hydrogen being also exhaled);§ hence it is concluded that the black precipitate is merely a mixture, as before stated. Some remarks may be added, after the red sulphuret or cinnabar has been mentioned.

2. *Deuto- or per- or bi-sulphuret—cinnabar—vermilion.*—The first three are names of system, the last two of commerce and the arts.

(a.) *Formation.*—*By subliming the black substance (proto-sulphuret) of either of the above processes; the sublimate is red.*

(b.) For an experiment, in the small way, to 1 part of *melted sulphur* add 4 of *mercury*, with agitation; if the mixture takes fire, cover the crucible; when cold, pulverize and *sublime the mass* in a Florence flask, or better in a matrass with a long neck, the heat being gradually raised to redness. It is superfluous to rectify the cinnabar six or seven times, by as many sublimations, in succession, as some

* Eng. Quart. Jour. Vol. XVIII, p. 298.

† The union is quick and intimate, for no metallic globules are perceived by the microscope, as in the former instance.

‡ This does not, however, prove that the mercury was free before the pressure, since many compounds are decomposed by a slight pressure, and their elements are freed or pass into new combinations, as is the case with most fulminating preparations, which are still regarded as chemical compounds. See Brande, in Eng. Quar. Jour. Vol. XVIII.

§ Ann. de Chim. et de Phys. Vol. I, p. 424. Laugier, Cours, &c. Vol. II, p. 814.

chemists recommend; for when it has been well performed, the product is very pure and beautiful, after the first.* For the purposes of the arts, this cinnabar is manufactured on similar principles, in the large way, especially in Holland.†

(c.) *Properties.*—Color scarlet, with a degree of brilliancy, dependent on the mode of preparation; *sp. gr.* about 10.; tasteless; unaltered by the air; burns with a blue flame.

(d.) *Decomposed by heating it with 2 parts of iron filings* and many other metals, or with fixed alkalies and alkaline earths, which engage the sulphur, while the mercury is vaporized.

(e.) *Loses its color by trituration with sulphur or mercury*, becoming black; detonates by passing through an ignited tube, owing to vapor of mercury; very little affected by the acids, except the nitric and sulphuric, which decompose it by heat.‡

(f.) *It occurs native*, and is the source of the mercury of commerce.

(g.) *Composition.*—Mercury, 1 equiv. 200+2 equiv. of sulphur 32=232, its equivalent. Those who regard the black sulphuret as a regular combination, assign to it 1 equiv. of each constituent and make its number of course 216. Mr. Brande is of the opinion that it is a regular compound, in definite proportions.§

(h.) *Sulphuretted hydrogen acts decidedly upon mercury and its combinations; it tarnishes the metal and precipitates its saline solutions black*, forming a sulphuret, and when heated, bi-sulphuret is sublimed, as already stated. The alkaline hydro-sulphurets produce similar effects.

VI. THE ACIDS sustain an important relation to mercury. All of them either dissolve the metal or unite with its oxides; and connected with their action, are many remarkable and interesting phenomena.

1. Sulphuric acid.

(a.) In the cold, no action.||

(b.) *The compounds vary with the proportions of the ingredients and the strength of the acid.*¶

* Fourcroy.

† See Ann. de Chim. Vol. IV, p. 25; Atkins' Diet. Vol. II, p. 87; Thénard's Chim. 5th edit. Vol. I, p. 582; Gray's Op. Chem. p. 727.

‡ When finely pulverized, it is known by the name of *vermilion*, and is much employed in the finer kinds of painting. The intenseness of the color being intimately connected with the purity of the materials, this circumstance becomes a test of the goodness of the preparation. It is used also in medicine, in fumigations, &c. When adulterated with red lead this not being volatile remains in the vessel after exposure to heat.

§ English Quart. Jour. Vol. XVIII, p. 292.

|| Employed sometimes to purify mercury, because, being agitated with it till the acid is no longer discolored, it combines with the foreign metals, while the pure metal is left.

¶ For many minute and curious observations on this subject, see Fourcroy, Vol. V, p. 435.

1. *Proto-sulphate.**

(a.) *Mercury 2 and strong sulphuric acid 3, with the heat of a lamp, or of a few coals, emit sulphurous acid gas, (Vol. I, p. 313;) the acid is in part decomposed, and the mercury thus becomes an oxide, which unites with the rest of the acid to form a mercurial sulphate.*

2. *Super-sulphate of protoxide.*

(a.) *Some free acid remaining upon the white salt, it is acrid, corrosive, deliquescent, reddens vegetable blues, and does not become yellow, either by hot or cold water.*

(b.) *The more acid the more soluble it is.†*

3. *Neutral sulphate of protoxide.*

(a.) *The super sulphate, being lixiviated with small divided‡ doses of cold water, till the latter ceases to redden test paper, a white and neutral sulphate is obtained, nearly insipid, and mild, unalterable by the air, and requiring 500 parts of cold, and 287 of boiling water for its solution.*

(b.) *Composition—(if dry) protoxide 1 equivalent, $208 + 1$ of acid $40 = 248$, its equiv. : (if crystallized,) 2 equiv. of water $= 18 = 266$; when the acid is in excess, it does not appear that it is very constant in its proportion.*

(c.) *Crystallizes from the hot solution in laminæ and needles.*

(d.) *With pure alkalies and lime water, the precipitate is greyish black.*

(e.) *The fixed alkalies precipitate the super-sulphate yellow, but ammonia throws down a little black oxide and, aided by the sun's rays, revives a part of the mercury, and with part forms a triple salt.*

Boiled, for a long time, till the excess of acid is entirely dissipated or decomposed, a sulphate of the per- or deutoxide is produced.

(f.) *If this salt, or either of the sulphates of mercury, is heated to a certain degree, sulphurous acid gas will rise, the salt*

* This salt is prepared in the large way, for the manufacture of corrosive sublimate and calomel; for corrosive sublimate, 50 lbs. of the metal with 70 of the acid, are boiled in a cast iron pan, to form 73 lbs. of super-sulphate. (Brando, quoted by Henry.) For pharmaceutical purposes, the sulphate is always prepared in this way. The neutral proto-sulphate is obtained with great ease, by adding sulphuric acid, or better an alkaline sulphate, to the proto-nitrate of mercury; the salt, being insoluble, is promptly precipitated.

† With 1-12 of its weight of acid in excess, it is soluble in 157 parts of cold, and 33 of boiling water.

‡ For otherwise it would become yellow, by the effect of the heat produced by the water and acid. It is said that a neutral sulphate may be formed by boiling equal parts of the acid and water, upon mercury.

will partly sublime, and we obtain running mercury, and pure oxygen gas.*

Sub-per-sulphate; sub-sulphate of deut- or per-oxide; turpeth mineral.

(g.) *If the salt†, last named, thoroughly dried by heat, the acid‡ being all removed, be washed with water, it is decomposed into insoluble sub- and highly soluble super-sulphate of mercury.*

(h.) *The precipitate with cold water is only greenish yellow, and not handsome.*

(i.) *I have found it important, not only to have the sulphate very dry, but thoroughly pulverized; any running mercury should be removed, by pouring it out, or if not practicable to remove all in this way, by corrosion with more acid; if it is then washed with copious streams of boiling water, andedulcorated by cold water, a beautiful yellow powder is produced, formerly and still, called turpeth mineral.§*

(j.) *The water takes most of the acid, and a small portion of the oxide, and thus forms a solution of super-sulphate; with ammonia, it gives a dark gray precipitate. A little acid still adheres to the oxide, and forms the yellow powder.*

(k.) *Properties.—Soluble in 2000 parts of cold, and 600 of boiling water; solution colorless; decomposed by heat,|| giving pure oxygen gas, and running mercury.*

Formerly considered as a pure oxide of mercury,¶ but it is evidently a sub-sulphate;** for when dissolved in muriatic acid, and examined by the muriate of baryta, it always gives traces of sulphuric acid.††

Remarks on the sulphates of mercury.

It appears then that there is

1. A sulphate of the protoxide of mercury,
2. “ peroxide “

* By stopping before the oxygen, and after the sulphurous acid comes over, the salt is found in the condition of yellow sub-sulphate.—Fourcroy. This is an instructive fact in connexion with the history of the turpeth mineral, or yellow sub-sulphate of mercury; see the text.

† Which may be prepared by adding sulphate of soda to the solution of the nitrate.

‡ If the acid is not all removed previously to the washing, the color is not good, and much of the powder is dissolved by the water.

§ From the vegetable convolvulus turpethum, which has a similar color.

|| In an earthen ware retort, or one of coated glass.

¶ Black, Vol. II, p. 518.

** Dr. Turner and Dr. Thomson state the composition of the turpeth mineral as being 1 equiv. of acid, and 1 of the peroxide. I have not seen the evidence that it contains so much acid, which appears the more extraordinary, as its properties do not indicate it, and the analogy with other metallic decompositions by water would not lead us to expect it.

†† Four. Vol. V, p. 441.

3. That the sulphate of the protoxide may be either a super or neutral sulphate.

4. That the sulphate of the peroxide may be either a super, a neutral, or a sub-sulphate.

Lt. Hopkins has also described a sesqui-sulphate of mercury, formed from the turpeth mineral.*

2. *Sulphurous acid.*—*No action on the metal*, but the red oxide, by contact with it, becomes white, and if there is much acid, the oxide is reduced in the sun's rays, and sulphuric acid is at the same time formed. If there is but little sulphurous acid, sulphite of mercury results.

3. *Nitric acid.*—*This is the best solvent of mercury*; the action is energetic, and produces a nitrate of the protoxide and of the peroxide.

1. *Nitrate of the protoxide.*

(a.) *With the common nitric acid*; sp. gr. 1.2; *the action commences in the cold*,† but if it is tardy, it may be begun and accelerated by heat.

(b.) *The single aquafortis* of commerce, readily dissolves mercury in the cold, and *is capable of taking up its own weight of the metal*. Place mercury in excess in a tumbler, and add the acid.‡ There is little action at first, but it soon begins with effervescence at the surface of the mercury, and if too rapidly, it may be checked by immersion of the vessel in cold water.§ Thénard, remarks that the nitrate obtained in this manner, always contains some hypo-nitrite, and that the crystals exhale nitrous acid if touched with sulphuric acid.

(c.) Nitric acid 3, and 5 parts of water, digested with mercury in excess and with occasional agitation, yields a pure proto-nitrate, which affords crystals by spontaneous evaporation.||

(d.) *Properties.*—*Crystals transparent white prisms; become yellow, and change their form, by exposure to the air*; when the solution stands just as it was formed, with mercury in excess, crystalline shoots,

* Am. Jour. Vol. XVII, p. 364.

† Not however if the acid be too strong or too weak.

‡ Mr. Dalton prescribes 500 grains of metal to 1000 water grain measures of acid, sp. gr. 1.2 H.

§ With a tall vessel and much acid, diluted, and in the cold, the solution is sometimes finished without the escape of a bubble of gas; for some time at least, the nitric acid absorbs the nitric oxide gas, and as in similar cases, becomes green, Vol. I, p. 456, but ultimately, unless artificially cooled, the fluid grows hot, and the gas breaks forth at the surface in red clouds of nitrous acid vapor, formed by the nitric oxide and the oxygen of the air; or if in a retort the gas may be received, colorless, in air jars. The expulsion of the gas destroys the green color of the solution, and it becomes limpid.

|| It would seem however, that in order to obtain crystals of neutral proto-nitrate, the solution must be slightly acidulated with nitric acid, otherwise the crystals will be those of sub-nitrate; water hot or cold, decomposes these salts and precipitates sub-nitrate, leaving super nitrate in solution. Mitscherlich in Ann. de Ch. et de Ph. V. XXXV. p. 421.

often rise, changing their form from day to day, and often leaving upon the most elevated point, a globule of metallic mercury.

(e.) *The solution made with heat and a diluted acid is of a light straw color; by exposure to the air, becomes less soluble and a yellow precipitate falls. The solution, made in the cold, is colorless, heavy, corrosive and tinges the skin, and other organic substances, of an indelible purple or black.**

(f.) *By spontaneous evaporation it affords transparent octahedral crystals, with truncated angles.†*

(g.) *This solution called mercurial water, is used in surgery, as an escharotic.*

(h.) *It is an important reagent especially in detecting the muriatic acid, in the analysis of mineral waters; for this purpose, the solution is made in the cold, and with a weak acid, when it can be diluted with water, without decomposition; otherwise a sub-nitrate is precipitated.*

(i.) *Composition. The neutral proto-nitrate contains 1 equiv. of acid, $54 + 1$ of equiv. of protoxide, $208 + 2$ of water, $16 = 280$ its equiv.; and the sub-proto-nitrate consists of protoxide 2 equiv. $= 416 + 1$ equiv. of acid $54 = 470$ its equiv. Precipitated by potassa, and soda, and their carbonates, black, being a mixture of protoxide and metallic mercury; by ammonia, grayish black; by sulphate of soda or sulphuric acid, white;‡ by muriatic acid and muriates, a copious white, caseous deposit; by sulphuretted hydrogen, black.*

2. *Nitrate of the peroxide—per- or deuto-nitrate.*

(a.) *When mercury is boiled in contact with nitric acid in excess,§ the acid is decomposed, emitting copious nitrous fumes; the metal then takes two equivalents of oxygen, and becomes a peroxide and of course a per-nitrate is formed. The same salt is produced by the spontaneous action of concentrated nitric acid.*

(b.) *By cooling, the solution deposits rhombic prisms, white and transparent, or in pearly needles.*

(c.) *When water is added, most of the acid, with a little oxide remains in solution, as a super-per-nitrate, while a little of the acid and most of the oxide falls, as a sub-per-nitrate; with cold water the pre-*

* According to Thénard, 5th ed. Vol. III. p. 288, neither the nitrate or hypo-nitrate of the protoxide, produces any stain, while the nitrate of the peroxide, stains the skin black, and the hypo-nitrite of the peroxide, stains it red; it would seem then that our mercurial solutions are commonly mixed, for according to my experience, they generally stain the skin.

† Fourcroy says however, (V. 453.) that he has observed them of four different forms, according to the state of the liquid.

‡ Granulated, and in small quantity; nor, if the precipitant has been sparingly used, does it appear, in less than one hour.

§ If of sp. gr. 1.2, Mr. Dalton recommends 350 grains of mercury, to 1000 water grain measures of acid.

precipitate is white, becoming greenish yellow,* with hot water bright yellow; by continued washing it is said that all the acid is removed, and the peroxide remains. This was formerly called *nitrous turpeth* it being analogous in composition to the other turpeth. Heat properly regulated, produces a similar effect with the nitrates, and the air converts the proto-nitrate into the same substance.

(d.) Solution of the *per-nitrate* is precipitated, a yellow hydrate, by alkalis; by sulphate of soda yellowish; with the muriatic acid and the muriates there is no precipitate, if there is sufficient water; *sulphuretted hydrogen* gives a black deposit, and recent muriate of tin a white.†

(e.) The solution of *this salt* is more acrid than that of the *proto-nitrate* and reddens vegetable blues.

(f.) Solution of the *per-nitrate*, by boiling upon more mercury, dissolves a portion, imparting oxygen from its oxide without decomposing the acid, and thus there is no discharge of nitric oxide gas.

(g.) The *nitrate of mercury* sparkles upon burning coals; mixed with phosphorus or starch, with a hot hammer, it detonates violently, and the mercury is reduced.

(h.) *Composition.* Acid 2 equiv. 108 + 1 equiv. of *per-oxide* 216 = 324; in the sub-per-nitrate, these proportions are reversed.

Ammonia forms triple salts with the *nitrates of mercury*, decomposing them first and then uniting with the oxide and acid; that of which the protoxide is the basis, is composed of protoxide 88.95, ammonia 2.46, acid 7.32, corresponding to 2 equiv. of nitrate of ammonia and three of protoxide of mercury; that of which the peroxide is the basis, is composed of peroxide 81.53, ammonia 4.68, acid 4.33.‡

Decomposition of the nitrate of mercury by heat, to form the red oxide or red precipitate.—This subject has been chiefly anticipated under the oxides. It is sufficient to add here, that the red precipitate found in the shops is prepared in this manner; the nitrate, prepared with heat and excess of acid, is decomposed by heat till all fumes cease, keeping the heat below that point at which the oxide would itself be decomposed. It yields 180 cubic inches of oxygen gas from an oz. of the precipitate, and the mercury is reduced. It is not used internally; it is employed as an escharotic, and in chemistry to afford oxygen gas, and in forming prussiate of mercury. Its composition has been already

* A small redundancy of acid prevents this precipitation.

† In our common solutions, both nitrates being more or less mixed, the indications by tests are not exact; but solution of common salt will throw down all the protoxide in the form of calomel, and then potassa will precipitate the peroxide yellow.

‡ This mixed nitrate answers most purposes in chemistry, and in the arts, as in felting, in making citron ointment, in blacking the hair, &c. (Laugier, Cours, &c. V. II. p. 325.)

§ Ann. de Ch. et de Ph. Vol. XXXV. p. 426.

given. The nitrates of mercury precipitate the metal upon bright copper, and upon many other metals.

4. *Phosphoric acid*.—*Phosphate of mercury is formed by double exchange between the nitrate of mercury and the phosphate of soda.**

5. *Acetic acid*.—*Acetate of mercury*.—*Nitrate of mercury and acetate of potassa are mingled boiling hot, and acetate of mercury is thus formed. The precipitate must be washed in distilled water, and is the basis of the celebrated Keyser's pill, an empirical remedy.*

6. *Muriatic acid has little or no action on mercury; but by a peculiar action with its oxides, two remarkable compounds, anciently and still known by the name of corrosive sublimate and calomel, are produced.*

Remarks.—*There has been a fluctuation of opinion regarding the nature of these bodies; they have been called muriates, and the difference between them has been attributed to a difference in the proportion of oxygen in the oxides, and of acid in the muriates, calomel being supposed to be a muriate of the protoxide, and corrosive sublimate a muriate of the peroxide; the former has also been called sub-muriate, and the latter oxy-muriate, and super-oxy-muriate. Since the present views of the nature of chlorine and muriatic acid have been admitted, these compounds are regarded as chlorides; calomel is a proto-chloride, and corrosive sublimate a deuto- or perchloride, and they become muriates only when in solution,† or when acted upon by watery agents; nor even then, according to Berzelius.*

On account of their great importance, their frequent use, and their widely different properties, the one being a safe medicine, and the other a virulent poison; and as the systematic names, even if they should be changed no farther, are liable to be easily mistaken, especially by uninstructed persons, it is obvious that the old names should be retained, as they can lead to no mistake, and one of them indicates the virulent properties of the substance, as the other name alludes to the mild properties of the corresponding preparation. Life and death should not, in prescriptions, be trusted between sub and oxy, or super-oxy; or proto and deuto; or *proto and per*, which may easily be misapprehended.

VII. CHLORINE.—*Chlorides.*

Remarks.—*All that relates to the muriates of mercury will be given under the chlorides of that metal which are the most important of all the metallic chlorides.*

1. *Mercury heated in chlorine gas, or made to arrive in it in the state of vapor, burns with a feeble blue flame, and produces per-chloride of mercury, a substance exactly analogous to corrosive sublimate.*

* It is sometimes used in forming a mercurial ointment.

† Only corrosive sublimate is soluble in water.

In treating of the chlorides of mercury, it will be most convenient to begin with the per-chloride, or corrosive sublimate, as the proto-chloride, or calomel, is usually formed from it.

CHLORIDES OF MERCURY.

The processes for these compounds are numerous, and have been often varied.

CORROSIVE SUBLIMATE, bi-chloride, per-chloride or deuto-chloride. Processes.

(a.) *To a solution of the per-nitrate of mercury, (nitrate of peroxide,) add muriatic acid, or any dissolved alkaline or earthy muriate, and muriate of peroxide will be formed, which by evaporation will be obtained as a solid or crystallized chloride.*

(b.) *The usual process of the manufacturers is to form per-sulphate of mercury,* by dissolving 50 parts of the metal,† with 60 or 70 of the acid, which gives three parts of super-sulphate of mercury; add and intimately mix 120 parts of dried common salt. Some add 10 parts of black oxide of manganese, and with a sand heat, gradually increased, the corrosive sublimate, 63 to 65 parts, rises and is condensed in a crystalline mass, in the dome‡ of the vessel;§ some calomel is also formed but being less volatile, it is condensed below the corrosive sublimate, and is easily distinguished from it by want of taste, and its insolubility in water.*

(c.) *A cheaper process|| mix equal parts dry per-nitrate of mer-*

* This is known to be in the condition of per-sulphate, by being precipitated yellow by pearlsh water, instead of black.

† Some add one fourth as much black oxide of manganese as mercury; its oxygen may aid in the oxidation of the metal, or in the decomposition of the muriatic acid to liberate the chlorine.

‡ If the sublimation is performed in a low retort, with a short and wide neck, into a large receiver, using a quick fire, the process is shortened, and the sublimate is not liable to melt and run back upon the materials, as in the other case.

The following statement of the decomposition and results obtained in this process, accounts for all the principles.

The quantities required for mutual saturation are, 1 equiv. of bi-sulphate of mercury, containing mercury 200 + oxygen 2 equiv. 16 = 216, or 1 equiv. of oxide of mercury + acid 2 equiv. 80 = 296, its equiv.; and chloride of sodium 2 equiv. containing 2 equiv. chlorine, 72 + 2 equiv. of sodium, 48 = 120: now the products of the decomposition will be distributed as follows; there will be 1 equiv. of bi-chloride of mercury, containing mercury 1 equiv. 200 + chlorine 2 equiv. 72 = 272, and sulphate of soda, 2 equiv. containing acid 2 equiv. 80 + soda 2 equiv. 64 = 144, and 144 + 272 = 416, and 296 + 120 = 416.—See Turner's Chem. 3d Am. ed. p. 353.

§ Mr. Brande's process, substituting parts for pounds.

|| I have found this process to succeed in the small way much better than when the mercurial salt and common salt are used alone; the sulphuric acid of the calcined sulphate of iron, appears to aid in the decomposition, and we never fail to obtain the corrosive muriate in beautiful white crystals: but the neck is sometimes so filled by them that the vessel is cracked, and we must then carefully avoid the fumes, which are highly noxious. Corrosive sublimate having been first manufactured at Venice, was called Venetian sublimate; the process was by 400 parts calcined sul-

ry, or turpeth mineral (yellow sub-sulphate) dry common salt, and calcined sulphate of iron, and sublime.*

Properties of corrosive sublimate, bi-chloride of mercury.

- (a.) *When sublimed, a white translucent mass, in beautiful needles.*
 (b.) *Taste highly acrid and burning, producing a constriction of the organs, and a long continued metallic taste; a virulent poison; a dose of a few grains kills;† it corrodes the organs; externally a caustic or escharotic.‡ In medicine not more than $\frac{1}{2}$ of a grain should be given for a dose, nor more than 1 grain in 24 hours.||*

phate of iron, 200 salt petre, 200 common salt, 180 quicksilver, 50 of the residuum of a former operation, 20 of impure sublimate, moistened with the impure acid distilled over in former processes; and then proceeding to sublimation by a sand heat, in glass bolt heads, with capitals and receivers. So complicated a mixture would be used only for cheapness; it is not difficult however to explain the operation of the different ingredients.—Gray's Op. Chem. p. 730.

* The red oxide of mercury unites with the muriatic acid, without disengagement of gas, and a spontaneous crystallization of the per-chloride (corrosive sublimate) follows.

† *Corrosive sublimate as a poison.*—A family having been alarmed by the black color of their tea made in a winter's morning, while it was still dark, gave some of it to a cat, and the animal was soon seized with violent vomiting: they then found, on examining the water still remaining in the bucket at the well, that it was discolored, and contained some foreign body, and the water was brought to me for examination. The bottle being agitated, the water appeared as if ashes were suspended in it; it was filtered, and the clear fluid gave a dark precipitate with sulphuretted hydrogen, and an orange or reddish precipitate with lime water and alkalies. Some of the solid matter remaining on the filter was thrown upon burning coals; it rose in a white cloud, but without any particular odor; some of it was heated in a coated glass tube, when it sublimed and condensed in a crystalline coat, acrid to the taste. Some of the grey powder from the water was heated with black flux in another glass tube, and globules of metallic mercury collected in the colder part. No additional evidence was needed that the substance was corrosive sublimate, and other facts evinced that it had been placed in the bucket with the intention of destroying the family. In cases where the quantity is minute, it is readily detected, as was first suggested by Mr. Silvester, by a simple galvanic circle. A clean zinc plate may be coated with a piece of gold leaf and a drop of the suspected fluid placed upon it; a metallic wire is then made to touch both the fluid and the zinc, and in a short time (if it contain mercury,) the gold leaf will be whitened and amalgamated. I find this method very delicate.* A laborer in this place mistaking a solution of corrosive sublimate for rum, swallowed a quantity that must have proved fatal; but a physician, in whose house it happened, gave him instantly a solution of pearl ashes which was at hand, and the corrosive sublimate being decomposed was rendered harmless. A gentleman in Baltimore, by the mistake of a servant, in giving him a solution of corrosive sublimate for cider, has recently (Aug. 20, 1830,) lost his life; such solutions should never be kept except in the most secure places.

Whites of eggs turn corrosive sublimate into calomel and are therefore used as a remedy; farina and gluten have a similar effect, and therefore a solution of starch or a mixture of flour and water may be swallowed with advantage; mucilaginous drinks and vomiting are auxiliaries. Mr. Orfila killed dogs with doses of from 6 to 12 grains of corrosive sublimate; they died in dreadful convulsions within two hours; but dogs that took larger doses with whites of eggs vomited and recovered. Corrosive sublimate beaten up with whites of eggs was rendered innocuous.

‡ Used externally very dilute for eruptions and sores.

|| Mur. Mat. Med. Vol. II. p. 205.

* Prof. Griscom finds that friction of a drop of the suspected substance, by a rod or wire of zinc or iron upon a strip of pure gold, about one third of an inch wide, discovers an almost infinitely small portion of mercury, by the whiteness which it produces.

(c.) *Soluble in from 16 to 20 parts of water at 60°, in 2 at 212°, and in 2 or 3 of alcohol, and also of ether*; camphor enables these fluids to take up much more corrosive sublimate. By evaporation it yields cubes, or rhomboidal, or quadrangular prisms.

(d.) *Reddens the tincture of turnsol*, (litmus,) but the color is restored by the muriates of the fixed alkalies* and earths; it turns syrup of violets green.

(e.) *Decomposed by several vegetable infusions*, as of bark, rhu-barb or camomile, and by several compound salts, as the soluble sulphates, phosphates, &c.

(f.) *Not alterable by the air, or by light*. Soluble at 70°, in half its weight of muriatic acid; becomes solid by a little reduction of temperature, and is obtained again, unaltered, by evaporation.

(g.) *Alkalies and alkaline earths† in solution, give a yellow precipitate*, soon becoming brick red;‡ ammonia precipitates it white; this precipitate is a compound of 1 equiv. of peroxide, 216 + 1 of muriate of ammonia 54; it is called in pharmacy the white precipitate of mercury, and is useful as the basis of a mercurial ointment.

(h.) *Several metals*, as arsenic, bismuth, antimony, and tin, and their sulphurets decompose it by heat.

(i.) *Uses*.—*In refining gold and silver*; in museums of natural history, to preserve the articles from insects and vermin, which it poisons; and in medicine, as has been stated.

(j.) *The solution is regarded by most chemists as a muriate of the peroxide*; and it is generally admitted that the chloride of mercury, by solution, becomes a muriate, and the muriate, by drying or crystallization, becomes again a chloride; the theory of such changes was given under chlorine.

(k.) Sulphuretted hydrogen gives a dark precipitate, a sulphuretted oxide.

(l.) *Composition*.—*Chlorine, 2 equiv. 72, + mercury, 1 equiv. 200, = 272 its equiv.* A triple salt is formed between this corrosive muriate and muriate of ammonia, formerly denominated *sal alembroth*, or salt of the wise. Other triple salts are formed between it and the muriates of potassa, soda, baryta, and magnesia, by all of which it is rendered more soluble.

Chlorate of mercury was described by M. Chenevix in 1802; it was formed by passing the chlorine gas through the red oxide suspended in water.

* See Ann. de Chím. et de Ph. Vol. XXXIV. p. 143, in which Bonsdoff contends that corrosive sublimate is an acid, and forms neutral crystallizable compounds.

† A mixture of about 300 parts of lime water, and one part of the corrosive muriate is termed, on account of its acrimony *phagadenic water*, used for cleansing the skin from pimples, &c.—Four. Vol. V. p. 478.

‡ Thénard gives these colors in the opposite order; my experience is stated in the text.

2. Calomel—proto-chloride of mercury.

Processes.

(a.) *Corrosive sublimate* in powder is *rubbed*, in a glass or porcelain mortar with half* its weight of mercury, till the latter disappears;† *sublimation is then performed*, in a glass vessel and the calomel will form a crystalline cake, in the dome of the vessel; sometimes it is sublimed a second or third time.

(b.) *A sulphate of protoxide of mercury is formed*, as described under corrosive sublimate, only, for 50 lbs. of mercury we use 40 or 45 of sulphuric acid, stopping the action when pearlash water gives the black precipitate of protoxide instead of the yellow of the peroxide; the common salt is added without manganese, and the calomel obtained by sublimation.

(c.) *Sulphate of mercury, being formed in the same mode as for corrosive sublimate*, 62 lbs. of this salt are rubbed with 40½ of mercury, till the latter disappears; the mixture is then sublimed with the addition of 34 lbs. of common salt, and from 95 to 100 lbs. of calomel, are obtained.

(d.) If the diluted, slightly acid proto-nitrate of mercury, is added to a solution of common salt, acidulated by muriatic acid, till precipitation ceases, the white precipitate is calomel.‡

(e.) To prevent the possibility of the mixture of corrosive sublimate with calomel, the latter is *finely pulverized*,§ and *washed abundantly with hot water*, till it comes off tasteless, it should not give a yellowish red precipitate; if any, it should be black.

PROPERTIES.

(a.) *White, insipid, not decomposed by heat; volatile*, but less so than corrosive sublimate; does not change in the air;|| *insoluble in*

* Equal weights.—Gray.

† The materials should be slightly moistened, and the mortar held under a vent, or at least, the operator, should secure his nostrils, by a handkerchief tied over them.

‡ This is the calomel of Schæele; the faculty have found it sometimes too prone to produce purging, and its properties have not been uniform. This is supposed to be owing to its having been formed from a per nitrate, which in the usual mode of preparing nitrate of mercury, is often made with the proto-nitrate, and therefore when the solution of salt is added, the water of the latter precipitates sub-nitrate of mercury along with the calomel. If the latter is made in the humid way from the proto-nitrate prepared in the cold, with a diluted acid, and an excess of mercury, then, water will not decompose the nitric solution, and the precipitate will be calomel alone. Corrosive sublimate is also formed with the per-nitrate, but if that is present, this being soluble is not precipitated, or it can be removed by washing.

§ Calomel is easily obtained in a fine white powder, by subliming it in low wide retorts, into double necked receivers filled with steam; the heat prevents the condensation in the neck of the retort, and as soon as it meets with the steam, it falls in an impalpable white powder; common calomel is of a dead yellowish white.

Gray.
In Howard's improved process, the vapor passes into water, which effectually frees the calomel from corrosive sublimate.—J. G.

|| Usually stated to be blackened by the light, but this effect I have never observed.

water, or requires 2000 parts to 1; insoluble in alcohol; two pieces rubbed together in the dark, are said to phosphoresce.

(b.) As sublimed, it is a heavy dull white mass,* semitransparent. By slow sublimation crystallizes in small prisms.

(c.) Decomposed by various compound salts, and by *alkalies* and *alkaline earths*, which give a black precipitate of protoxide of mercury, formed, as is supposed, by the decomposition of water whose oxygen goes to the metal to produce an oxide, and its hydrogen to the chlorine to form muriatic acid.

(d.) Not soluble in *muriatic acid*; chlorine and nitric acid make it pass to the state of corrosive sublimate.

(e.) Not poisonous; a mild purgative, and used for other medical indications; an article of great value.†

(f.) *Composition*.—Mercury 1 equiv. 200 + 1 equiv. of chlorine 36=236, its equivalent. Corrosive sublimate, has 2 equivalents of chlorine, which appears to be the only difference of composition in these two bodies, so closely allied in constitution, but so widely opposite in properties.

The salts of mercury that have not been named, may be formed either directly or by double exchange; all mercurial salts are decomposed by alkalies, and alkaline earths. Ammonia has a tendency to revive the oxides, which it precipitates, and it sometimes forms triple compounds, with a portion of the salts, to which it is applied.

Bi-chromate of mercury.—Obtained by mingling solutions of chromate of potassa, and acid proto-nitrate of mercury; the precipitated powder is washed with boiling water; its color is red,‡ as I have observed it; it is commonly described as yellow.

VIII. IODINE.—There are two iodides.

1. *Prot-iodide*.

(a.) Formed by mingling *hydriodic acid* or *hydriodate of potassa* with *proto-nitrate*, or some other proto-salt of mercury.

(b.) By heating or grinding mercury and iodine together; the former process is the best,§ and the latter is apt to produce the deut-iodide.

(c.) Color a fine yellow, and it consists of mercury 200, 1 equiv. + 1 equiv. of iodine 125=325 its equiv.

* Sp. gr. about 12 or more. Fourcroy, Dr. Hope.

† "It is given in affections of the liver or neighboring organs, in cutaneous diseases, chronic rheumatism, tetanus, hydrophobia, hydrocephalus, and febrile affections, especially those of warm climates. Its anthelmintic power is justly celebrated; and it is perhaps superior to the other mercurials, in assisting the operation of diuretics in dropsy."—*Mur. Mat. Med. II.* 209.

‡ A. A. Hayes, *Am. Jour.* Vol. XIV, p. 144.

§ For a class experiment, iodine may be thrown into a glass tube full of water, containing pieces of phosphorus; on warming it, hydriodic acid is instantly formed with effervescence, and is immediately fit for the precipitation of metals from their solutions.

2. *Deut-iodide.*

(a.) *Formed as above*, except that the mercurial solution must be that of a per salt; both precipitates being soluble in excess of the mercurial salts, and in the hydriodate of potassa, we must take care not to add too much of either. Neither of them is soluble in water.

(b.) *Of a brilliant red*; I have observed that it becomes more intense by standing some hours in the fluid, in which it was precipitated. It is a splendid pigment.*

(c.) *Composition*—Mercury 1 equiv. 200 + 2 equiv. of iodine, 250 = 450 its equivalent.

IX. CYANURET, (Prussiate of mercury.) For a short notice of this compound, see Vol. I. p. 417. It will be mentioned again, in a fuller account of the prussic compounds, under animal substances.

Fulminating Mercury.

1. *Discovered accidentally by Mr. Howard*, about thirty years since,† while he was operating upon oxides of mercury, with nitric acid and alcohol.

2. *Processes.*

(a.) *Process of Mr. Howard*.—500 grains of mercury are dissolved with a low heat, in $7\frac{1}{2}$ measured oz. of nitric acid; after the solution is cold, 2 oz. measures of alcohol are added for each 100 grains of mercury, and the action aided by a gentle heat; a white fume appears, and a white or gray powder precipitates as the action proceeds. Prof. Griscom uses with success, 150 grs. of mercury to $1\frac{1}{2}$ oz. of acid and 2 oz. of alcohol.

(b.) *Dr. Woodhouse*,‡ directed, to take 2 oz. measures of saturated solution of nitrate of mercury in water, add 4 oz. measure of strong alcohol and then 2 oz. measure of strong nitric or nitrous acid.

(c.) *Another process.*§

In my own experience, for many years, the following arrangement has never failed. Single aqua fortis is added to mercury, in excess, in a tumbler, and allowed to stand over night in the cold; the proto-nitrate, thus formed, is agitated to mix the solution equally. One measure of it, in a large tall glass, (a quart tumbler will do,) is placed under a vent and an equal measure of the strongest nitrous acid|| is added;¶ then 1 measure of good alcohol is also added, cautiously,

* By sublimation, it may be crystallized in rhombic tables of a fine yellow color; the slightest friction disturbs the molecular arrangement, and the color changes to a splendid scarlet.—A. A. H.

A periodide is left in preparing iodide of cyanogen, by heating a mixture of iodine and cyanide of mercury.—J. T.

† See Phil. Trans. 1800.

‡ Med. Repos. Vol. V. p. 92.

§ The process under a has sometimes failed with me or succeeded only partially, and that under b, although an improvement on the original one, is attended with too violent an action especially towards the end, which diminishes the product.

|| Such as is described Vol. I, p. 447.

¶ It is material that the acid should be added first, for the alcohol, by taking the water of the solution, precipitates the nitrate, and probably decomposes it in part into sub-nitrate, as the precipitate is usually yellow.

by little and little, (lest the acid should act too violently;) no heat will be needed; in a few minutes little explosions will be heard at the bottom of the glass and gas will rise abundantly; more alcohol may be required from time to time, to keep the action at the proper point, which is that of a lively effervescence, with abundant white fumes flowing over the lip of the vessel; if the fumes become red and break forth with violence, more alcohol will keep them down; on the other hand, should the action be too languid, more nitrous acid may be supplied, and thus the operator can exactly regulate the activity of the process; 3 or 4 measures of the alcohol are usually employed for 2 measures of the nitrate and 1 of the acid. When the powder that is formed no longer increases, and especially if it begins to diminish, water may be added to check, and finally to stop, the action.* *The precipitate, being liable to the reaction of the acid, must be immediately collected on a filter, washed with pure water and dried; it is usually done by the heat of a water bath.†*

(d.) *Purification.*—*Repeated washings with cold water, upon the filter, are generally sufficient; there is some loss, as the substance is moderately soluble in cold water; it is readily dissolved in boiling hot water and crystallizes in needles by cooling.* It should be left to dry upon the filter, which should be laid upon coarse papers till it ceases to moisten them, and then secured upon a board, which may remain over night in a warm place.‡

Properties.

(e.) *A white or gray powder; often in small distinct crystals;*

* The alcohol and especially the acid, of the shops, rarely succeed well in forming fulminating mercury, and almost always require heat which it is desirable to avoid; when of the best quality, they will answer, but the practical chemist will find it necessary, for this purpose and many others, to prepare the acid and alcohol for himself.

† From 100 grs. of mercury, about 100 or 120 grs. of the powder are obtained.

‡ In the morning, the paper may be cautiously taken up by its angles, gently stretched and twisted, and the powder that will roll off may be received on a clean paper, and if there is occasion, the filter may be farther dried, and very slight friction, as by a quill or a wooden or ivory knife, may be used to detach the remainder. It should then be divided into a number of parcels, on as many cards, and laid separately, so that each should contain not more than 30 or 40 grains; a very slight pressure, before the powder is quite dry, may be used to cause the lumps to crumble down; the parcels may then be left for another night in a warm place and they will be perfectly dry by morning, when the respective powders may be very gently moved, by the filaments of a quill, to detach the crystals, which are apt to be in little clusters. Last of all, several of the parcels may be cautiously added together, in a case of paste-board, which may be covered by a loose card and placed in security. The case, when it is moved, should never be laid in the palm of the hand, which would be destroyed by an explosion; it should be lifted by one corner or the edge, with merely the thumb and finger. It is not uncommon to keep the powder in a vial, stopped by a cork, or in a wooden box; the above is however the safer arrangement.

§ The gray color may perhaps arise from minute portions of metallic mercury; in bad processes, it is common to find numerous distinct globules mixed with the fulminating crystals.

inodorous; taste metallic; does not affect test colors; remains unchanged from year to year; very little if at all affected by the light.

(f.) *Detonates by the hammer and anvil*; the containing surfaces are sometimes indented. It explodes, by heat, at 368° ; also *by flint and steel,* by electricity, by galvanism, on burning coals, by friction, by sulphuric acid*; not more than from 3 to 5 grs. ought to be used in these experiments.

(g.) If dry sand is carefully mixed with the powder, by a feather, it will then scarcely bear any pressure; a little being laid on an anvil and the hammer merely moved upon it, by drawing it without a blow, will produce a violent explosion.

(h.) Ten grs. of the powder, in the centre of a 7 inch glass globe, being exploded by the electrical spark, the globe, was not burst, but was lined with metallic mercury.† If the powder is strewed through a long glass tube, 1 inch in diameter, (the neck of a glass retort answers very well,) it may be fired commonly without bursting the tube, which will be coated over, so as to be in some places a mirror.

(i.) *The inflammation of this powder does not kindle grains of gunpowder*, mixed with it. It is so rapid that it has not time to fire the powder; it throws it aside and the grains are found coated with mercury. Lay a train of gunpowder, of several feet in length, and a parallel one of fulminating mercury, (which is easily done by jarring it from a bent card and shaping the train by the feather of a quill;) connect them by a cross train of gunpowder and fire the latter; the mercurial powder will flash vividly, from end to end, like lightning, and the gunpowder will burn with comparative slowness.

Lay a train of gunpowder; then continue it by a train of mercurial powder, and continue this last with another train of gunpowder; thus,

Gunpowder.	Mercurial powder.	Gunpowder.
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Fire it at either end; the train in the middle will explode, but that

* Stop the touch hole of a pistol with wood or wire; fill the pan, cautiously, with the fulminating powder, by pouring it from a bent paper; close the pan with a pair of pincers and fire it in the usual way; there is a slight explosion, with a bright flash, and the contiguous parts of the pistol and of the hand are coated with metallic mercury. Mr. Howard found that a charge of it, sufficient to propel a bullet with more force than an ordinary charge of gunpowder, always burst the piece. 17 grs. did not burst a fowling piece, and the ball had but half the force which an ordinary charge of the best gunpowder, viz. 68 grs., would have given it; 34 grs. of the fulminating powder tore the breech of the gun into many pieces. In cannon, it was found to have very little effect; it shattered the balls to pieces, and tore the iron box which contained them.

† This experiment I have several times repeated, with the same result, but I have known it to burst; the operator should therefore be at a distance, and may, by electrical wires, or by a train of gunpowder, make the discharge in another room.

§ I have usually held it in my hand and fired the powder by a hot iron, but as it sometimes bursts, it is well to place it where it can be fired by a long, heated iron rod.

at the other end will remain. Now repeat the arrangement and fire it in the middle, and neither train of gunpowder will be inflamed.

(j.) *Its force is irresistible within certain small limits*, but the re-vivification of the mercury and the quick condensation of its vapor, very much circumscribe its effects. The experiment of the globe and tube (g.) prove the latter; the following may be added. Bore a hole in two blocks of firm wood, to the depth of three or four inches and of the diameter of a goose quill; charge one of them with gunpowder and the other with the mercurial powder, (by pouring it slowly and without pressure from a bent card;) the first block may be fired in the hand and the powder will burn only with rapid flame; the other block being laid behind a barrier and fired by a train of of gunpowder, produces a violent explosion, which tears the wood into fibres all around the hole, for a space of three or four inches in diameter, and, perhaps, rends the block* in pieces.

THEORY.—I shall postpone this part of the subject until we come to fulminating silver, which is a compound of the same nature. It will be sufficient, for the present, to observe, that these preparations are true saline compounds of oxide of mercury with a peculiar acid, called the fulminic, and supposed to be identical with the cyanic.† It has carbon and nitrogen for its basis, and this, united to oxygen‡ form the acid, so that the ultimate elements of this fulminating preparation are mercury, oxygen, carbon and nitrogen, and the explosion is owing to their reciprocal action and the products that arise from it. The subject will be resumed under silver and finished under prussic acid in connexion with animal substances.

X. ALLOYS.—*Mercury unites with most of the metals*, and the alloys are called *amalgams*.§

General properties of amalgams.

Both liquid and solid, according to the proportions; sodium 1 and mercury 1 form a solid; 15 of mercury and 1 of tin are fluid; when fluid the amalgams are less so than mercury; when solid, they are often brittle; color white; exhibit a crystalline structure; and are capable of crystallizing in definite proportions; for this purpose, they are

* I have known, in two instances, piles of the fulminating powder lying unconfined to tear a hole through a thick board or plank, (Am. Jour. Vol. I, p. 168.) In the latter case, the plank was an inch and a half in thickness. The pile of fulminating mercury (100 or 150 gra.) was covered by a large glass bell, which did not touch the powder, but it somehow exploded at the moment that some of the mercurial powder was flashed; at the distance of a few feet. The glass bell was not exploded, although it broke by the fall, nor were contiguous persons or glasses injured.

Perhaps the powder might be useful where a great initial force is wanted, as in rending rocks, but much caution is necessary in preparing, keeping and using it.

† See Vol. I, p. 417, and Am. Jour. Vol. XVIII, p. 337, for the views of Dr. Ellet.

‡ And as some imagine to mercury, for it has been supposed that the acid contains a portion of the metal as one of its elements, but Gay-Lussac and Leibig regard it as stated in the text.

§ From *agua yameo*.

combined by heat with 5 or 6 parts of mercury, a portion of which is distilled off and the remainder allowed to cool slowly, when the amalgam crystallizes, a part remaining fluid; all are decomposed by considerable heat, and some spontaneously in the air, as those of potassium and sodium.* Some amalgams are made by mere contact, as of gold, silver, tin, &c.; others require the fusion of the solid metal, and others still, whose melting point is above that at which mercury boils, require particular precautions. In the amalgams, one metal supplants another, so that the affinities for mercury are different. Mercury renders most metals with which it unites brittle.

1. **ARSENIC** unites with mercury by long agitation over a fire.

2. **ZINC** unites with mercury, either by trituration in a mortar, or, better, by fusion, the mercury being dropped in. In the usual amalgam, made to excite electricity, the proportions are 1 part of zinc to 2, 3 or 4 of mercury; it may be occasionally softened by trituration in a mortar, with or without the addition of more mercury. A better amalgam is made of equal parts of tin and zinc, and as much mercury.

3. **BISMUTH**.—*The union is easily effected, either by trituration, or, by pouring hot mercury into melted bismuth.* With 2 of the former and 1 of the latter, the amalgam is at first soft, but becomes hard; by slow cooling it crystallizes; with mercury in excess it remains fluid, dissolves lead, still remains fluid, and may be filtered through shamoy leather without decomposition. With this amalgam (which although solid becomes very fluid by farther amalgamation,) mercury is often adulterated, and if there is as much as 70 or 80 per cent. of mercury, the fluidity is not much diminished, but the sp. gr. is too small and it draws a train† as it is moved on glass. It is purified by distillation.‡ It is also oxidized more easily.

4. **TIN** and mercury readily unite, even when cold, and by pouring mercury into melted tin, they combine apparently without limit. With 1 tin and 10 mercury the amalgam is very fluid; 3 of tin and 1 of mercury crystallize in cubes or plates; equal parts form a solid compound. With 1 part bismuth and 4 of mercury, the amalgam is fluid at a very low heat, and being applied, warm, to clean, dry, and warm glass, it adheres and forms a brilliant coating; it is thus that glass globes are lined.§

* Thénard, Vol. I. p. 617.

† In the language of the apothecaries it *draws a tail*.

‡ To try the purity of mercury, dissolve it in nitric acid in the cold; water then precipitates the white oxide of bismuth, but not the mercury; next, precipitate by muriatic acid; collect, and dry the precipitate, and by heat expel every thing volatile; the muriate of lead will remain in the vessel, but the muriate of mercury will sublime.—*Fourcroy*.

§ By turning the globe round and round, the whole inside may be thus smeared with the amalgam, so as look like a metal globe highly polished; but, when held between the eye and window, we observe that it is covered only with a cobweb of the metal.—*Black, Vol. II. p. 550.*

Silvering of glass.—A piece of tinfoil lying on a table is covered by quicksilver, which is gently rubbed with a hare's foot to aid the union, and when this happens it becomes very splendid, and is said to be *quickened*; the glass plate, clean and dry, is now cautiously slid upon the tin leaf, so as to sweep off the redundant quicksilver; leaden weights are then applied and removed as soon as the tinfoil adheres. It takes 2 ounces of quicksilver for three square feet of glass.* Sometimes the tinfoil is placed on the glass, and the mercury upon that; the redundant quicksilver is swept off by another glass, slid over, and paper and a board being laid on the tin, it is strongly pressed with weights to produce the adhesion, and to expel air and superfluous mercury; the plate may be inclined to favor the draining.

For a class experiment, a neat method of silvering a glass plate is to form an amalgam of 1 part bismuth and from 2 to 4 of mercury, heated together till the mercury begins to evaporate, then poured into cold water and strained through 3 or 4 thicknesses of cloth; place this upon the tinfoil, and a smooth white paper on it; the glass is laid upon the paper, and the latter is dexterously withdrawn so as not to displace the amalgam, and the glass is at the same instant pressed down and weighted, and soon adheres.—*Prof. Hitchcock.*

5. **LEAD unites with mercury in the same manner and proportions as tin**; in either case mere contact† with the bright metal, especially with a slight friction, is sufficient; and the amalgam is fluid or compound according to the proportions; it is white and brilliant, and when composed of 1 part of lead, and $1\frac{1}{2}$ of mercury, is susceptible of crystallization.‡

6. **COPPER has little disposition to unite with mercury.** It may be done by pouring dilute solution of nitrate of mercury upon copper, recently precipitated from the sulphate by zinc, and well washed; the mercury is of course precipitated, and more is added, and trituration produces a reddish amalgam.—*Aikin.*

7. **ANTIMONY, in fine powder, by trituration combines with mercury with difficulty.**

XI. POLARITY.—Like other metals it goes to the negative pole.

XII. NATURAL HISTORY.—*Ores.*

* Watson, Essays, Vol. IV, p. 240.

† In consequence of this property mercury is sometimes employed to dissolve a musket ball in a wound, or a leaden tube or probe.—Bl. II, 551.

‡ The solid amalgam of tin, and the same of bismuth, by trituration in a mortar, became fluid, and if this is done in the palm of the hand, there is a sensation of cold, as great as is produced by the evaporation of alcohol. A rod of tin standing in the cold in this amalgam is, in a few days, corroded, and crystals of bismuth, with a little mercury will adhere to it. A compound of equal parts of the amalgams of tin, bismuth, and lead united at 212° and exposed for a few days to frost, will exhibit floating crystals of bismuth, nearly $1\frac{1}{4}$ of an inch long. Aikin's Dict. Vol. II, p. 2. A fluid amalgam is composed of 1 lead, 1 tin, 2 bismuth, and 4 mercury.

Mercury is not very generally diffused, it is found at Idria in Hungary, at Almaden in Spain, in Italy and Sicily, in South America, in the East and Spanish West Indies, and very small quantities in France and Britain, and in the Duchy of Deux Ponts, and in Siberia. It occurs native; as an amalgam with silver; as a muriate called horn quicksilver or corneous mercury, and lastly and chiefly as a sulphuret. This is the only one which is wrought. It varies from dark brown or black, to bright vermilion red; usual color red. Sometimes it is crystallized.

XIII. *Assay* and Extraction.*

In both the assay and the extraction in the large way, the native sulphuret is distilled with iron filings or lime, (in the large way with lime,) in earthen or iron vessels, connected with glass or earthen receivers containing water, the sulphur unites with the lime or iron, and the mercury distils over in vapor and is condensed. Even the native mercury is usually distilled to separate it from the earthy matters.

At Almaden, in Spain, where are some of the richest mines of mercury; they decompose the ore by a rude distillation, in a furnace so contrived that the vapor of the mercury which is disengaged by the heat is conducted into a cavity, in the upper part and on one side of the furnace, and is conveyed into aludels where it is condensed. No addition is made to the ore in this treatment.†

XIV. *Uses.*—They are for the most part sufficiently obvious from the details that have been given. Mercury affords some of the most valuable articles of the *materia medica*, and all of any note have been mentioned in giving its history.

This metal is eminently useful to science, both in physics and chemistry, and is used by the anatomist in making injections of delicate vessels and structures. But by far the greater part of quicksilver is consumed in silvering mirrors, in gilding, and in the extraction of gold and silver from the ores and mixtures, in which they are found.

SEC. XXXIV.—SILVER.

Remarks.—*Silver and gold are usually called the precious metals;* from their being used for coin, in modern as well as in ancient times, as well as from their superior beauty, they are still and probably always will be regarded as precious. *They are also called noble metals;* this refers not only to the reasons just stated, but also to the properties of malleability, ductility, inalterability by the air, even (in

* It may be rudely assayed, by strewing the ore in powder on a plate of hot iron, or on a hot brick and covering this with an inverted glass, when the mercury will rise in vapor and be condensed in globules.

† For details and drawings of furnaces, see Gray's *Operative Chemist*, see also Watson's *Essays*, Black's *Lectures*, Alkin's *Dict.*, Thénard's *Chem.*, and Fourcroy's *System*. Mercury comes to market done up in tanned skins of several thicknesses, corded and enclosed in small wooden casks. It also comes in bottles of iron, as it is little disposed to unite with that metal.

a good degree) when heated, and to the reducibleness of their oxides by heat alone, without the addition of combustible matter. If these properties are characteristic of noble metals, *platinum has every claim to be associated with gold and silver*, and there can be no objection to introducing it as a coin; for purposes of science, it is already in use, and also as an ornament, although it is less beautiful than gold and silver. In the sense in which the word noble has been applied to the metals, *we must include, besides gold, silver and platinum, nickel and palladium, in the designation of noble metals*; and mercury and cadmium approximate to the same characters. But in common language, only gold and silver are regarded as noble or precious metals.

I. HISTORY.—*In the earliest records, silver is familiarly mentioned, and in none more frequently than in the Scriptures*; excepting only gold,* the highest value has ever been attached to it. The alchemists labored long and perseveringly, to fabricate it from the baser metals and from other materials.

II. NAME.—*Latin argentum; Greek αργυρον; alchemical name Luna or Diana*; its astrological connexion was with the moon, to whose light it bears, when polished, no faint resemblance. Some epithets derived from the old names are still retained, as *Lunar*, for the caustic, formed from the nitrate.

III. PROPERTIES.

(a.) *Whitest† of the metals*, and when clean and pure, always beautiful, whether polished or not.

(b.) *Lustre inferior only to that of polished steel*; when highly burnished, nothing is more agreeable to the eye; when soiled, its lustre is easily renewed.

(c.) *Sp. gr. when cast, is 10.47; if hammered 10.51*; rendered somewhat more dense by mechanical treatment, but less than most metals; tasteless; inodorous, even by friction; *elastic and sonorous*, especially when alloyed;‡ not hard, *easily cut* by steel, but it is harder than gold.

(d.) *Malleability inferior only to that of gold*; silver leaf is $\frac{1}{100000}$ th§ of an inch in thickness, and is blown away by the slightest breath of wind.

(e.) *In ductility, after gold, platinum and iron*; wires can be drawn finer than human hair; a wire of $\frac{1}{16}$ th of an inch in diameter sustains 240 lbs.; a little copper increases its tenacity; less however

* The remark is of course restricted to substances well known to mankind; platinum was formerly more costly than gold, and potassium, sodium and various chemical and medical substances are still in that condition.

† Sometimes tarnished by sulphuretted hydrogen, floating in the air and arising from animal decomposition.

‡ In small quantity, adds to the sonorousness of bell metal, as already mentioned.

§ Ure's Dictionary.

than is found in silver money; the silver of silver wire bears a higher value in commerce than common coin; 1 gr. of silver will cover a wire 400 feet long.

(f.) *Fuses in a full red or white heat;** if pure it melts with a full red heat; I have seen thick basins and crucibles of pure silver melt at a heat short of whiteness, and a plate of the thinness of common paste board will melt in an active coal fire. When in fusion, if the metal is pure, its appearance is very brilliant, and resembles that of a polished mirror; but after it congeals, it is of a dead white; in becoming solid, it throws out little shoots or branches, and some portion is thus occasionally lost;† it can be crystallized in octahedra in the usual way.

(g.) Fixed in a heat not much above that at which it melts, but volatilized by a lens; also by galvanism and electricity, and even to a degree, by a very high furnace heat; fumes rise from it when urged by the blow pipe, which color a piece of gold brown, when held above, and the solar focus volatilizes enough of it to silver a lamina of gold placed over it, (Laugier.) It is also found in the chimneys of the silver smiths.‡

IV. RELATION TO OXYGEN.

(a.) *Not oxidized spontaneously in the cold air;* the tarnished crust is usually a sulphuret;§ slightly oxidized in a powerful furnace, especially if touching earthy|| matter with which the oxide can fuse into a glass.

(b.) *Silver leaf and wire burn brilliantly, with green light,¶ by galvanism and electricity.*

(c.) *In the focus of the compound blow pipe, silver boils, evaporates and burns; if pure, with a beautiful white light;* the copper alloy burns green; after the heat is raised, the hydrogen may be shut off, and the metal will burn in the oxygen alone. *If pure, it fuses with a white surface; if alloyed with copper it will be black.*

OXIDE.

(a.) *There is only one that is fully established.*

(b.) It seems almost certain, that an oxide is formed when the galvanic or electric discharge dissipates silver leaf or wire in colored fumes, or when the metal burns in the focus of the oxy-hydrogen blowpipe, but it is not easy to collect these fumes; probably they contain the same oxide that unites with acids.

* Commonly stated at 22° of W. which is obviously wrong, as this corresponds to 3937° F. † Hence in assaying, they allow the silver to cool very slowly.

‡ The current may however carry it up mechanically.

§ Observed to scale off from the silver images in old churches, owing to sulphurous gases from bodies beneath the pavements.

|| Silver being enclosed in porcelain balls and intensely heated for a long time, acquired a sufficient supply of oxygen gas through the cracks to form an oxide, which produced a glazing of a yellowish white upon the porcelain.

¶ Probably owing to copper.

(c.) The oxide is *easily obtained, by decomposing the nitrate* of silver by solution of lime or baryta,* or by potassa or soda; the precipitate is washed and heated to low redness.

(d.) It is *brown or deep olive, tasteless, insoluble in water*, does not affect the vegetable blues; not altered by light; it is readily dissolved by ammonia in excess.

(e.) *Composition.*†—Silver, 1 equiv. 110 + 1 equiv. of oxygen, 8 = 118 its equivalent.

(f.) *Oxide of silver is reduced* to the metallic state by heat alone, without the addition of combustible matter, oxygen gas being expelled; this is one of the attributes of a noble metal; combustible matter however facilitates the reduction, and at a very low temperature.

(g.) It appears that *melted silver, if pure, absorbs and retains oxygen gas while it is in fusion* with the access of air, but gives it up on *congealing*, which produces the jets that are observed when this metal becomes solid; if while in fusion it be plunged beneath a glass full of water, when it congeals, it emits gas of which 80 per cent. is oxygen; the presence of $\frac{1}{15}$ of copper prevents this absorption of oxygen gas from the air.

V. WATER, if pure, *does not act upon and is not affected by silver*; the tarnished‡ crust produced by silver plates standing in common water, is owing to animal and vegetable matter, and is ordinarily a sulphuret.

VI. RELATION TO COMBUSTIBLES.

1. Sulphur.—Sulphuret.

(a.) *Silver combines with sulphur and phosphorus; sulphur, by fusion, unites readily with silver*; for this purpose thin plates are stratified with sulphur and heated till the latter melts.

(b.) It has been already mentioned, that silver is blackened by sulphuretted hydrogen; its solutions are precipitated by it and by hydro-sulphurets, and in all these cases a sulphuret is formed.

(c.) *Color deep violet, almost black; lustre nearly metallic; opaque, brittle, soft, more fusible than the metal.* It exists native, forming the beautiful lead gray ore called silver glance or vitreous silver, which readily yields silver by the blowpipe and can be cut by a knife.

(d.) *Composition.*—Silver, 1 equiv. 110, + sulphur one, 16 = 126 its equivalent.

2. Phosphorus.—Phosphuret.

(a.) *Formed by fusing phosphoric glass, charcoal and silver together.*

* Baryta is preferred.

† Dr. Thomson and Mr. Faraday admit the existence of another oxide of silver in the black crystals that form on an ammoniacal solution of oxide of silver exposed to the air. Dr. T. supposes it to contain 3 equiv. of silver, + 2 of oxygen.

‡ Silver, as we have it in spoons, is tarnished by mustard, by an egg, by some shell fish, &c. Such phenomena probably often depend upon a galvanic action.

(b.) It is of a white granular and crystallized structure; is cut by the knife; phosphorus is volatilized by heat and silver left.

VII. ACIDS.—The acids that act most remarkably on silver, are the nitric and the sulphuric.

1. *Sulphuric.*

(a.) *No action in the cold; if concentrated and boiled** on the metal, sulphurous acid gas is given out and a *white mass obtained*; or if 4 parts of acid are used to 1 of silver in shreds or grains,† it becomes a clear dense liquor.

(b.) *The sulphate is more easily formed by adding sulphuric acid to the washed precipitate from nitrate of silver by carbonate of soda, or by adding the same acid or any soluble sulphate to nitrate of silver.*

(c.) *It is a dense white precipitate, little soluble in water but soluble in an excess of sulphuric or nitric acid, and forms a clear corrosive fluid, with a distinct metallic taste.*

(d.) From the solution in sulphuric or nitric acid, the sulphate *crystallizes in small brilliant needle-shaped crystals*, soluble in excess of acid, in 90 parts of water at 60°, and in less at boiling heat, so that it crystallizes on cooling.

(e.) *The sulphate easily melts, and in a strong heat, is reduced completely, with the emission of sulphurous acid and oxygen gas.*

(f.) *Decomposed by the muriatic acid to form a chloride; also by alkalis which precipitate the oxide, and ammonia dissolves both the sulphate and the oxide.*

2. *Sulphurous acid, or any soluble sulphite, forms a precipitate with nitrate of silver, or the acid dissolves the oxide; the sulphite crystallizes in small brilliant grains.*

3. *Nitric acid is the appropriate solvent of silver* and is almost the only acid ever used to dissolve this metal, either in the arts or in chemistry.

(a.) *If concentrated, it does not act on silver; it must be diluted with from 2 to 4 parts of water; common aquafortis requires an equal volume, and a moderate heat to begin with, or if hot water is added, no other heat is necessary; nitric oxide gas is abundantly emitted, and we obtain a solution, permanently green, if there be copper; otherwise the green is transient.‡*

* Using in a silver alembic an excess of sulphuric acid in decomposing fluor spar for its acid, I have more than once corroded the alembic, so that a hole was eaten through it; the heat of a few coals were applied.

† See Lucas' observations, Ann. de Ch. et de Ph. Vol. XII, p. 402, and Chevallot, Id. Vol. XIII. p. 299.

‡ Owing to the nitric oxide gas which forms a green solution with the acid. Boil a little towards the end to dissolve all the silver, and if gold be present, which is not unfrequent in the standard silver, it remains as a black powder, and can be fused with borax. If sulphuric or muriatic acid is contained in the nitric, they form a dense white coagulum which falls and should be saved to be afterwards reduced. When

Properties.

(b.) *If the silver and acid were pure, the solution is limpid; even in extreme dilution, it is caustic, bitter and styptic; stains the skin and dead animal and even vegetable matter permanently black; it stains ivory; it is the foundation of indelible ink, with sometimes a little lamp black.**

(c.) In preparing silver† for purification, I have sometimes dissolved in aquafortis, 25 or 30 dollars at once; the action is very vigorous and the red fumes of nitrous acid, the boiling green or blue fluid, and the white precipitate from the muriatic and sulphuric acid, usually present in the acid of commerce, form a very striking contrast; the concentrated hot solution crystallizes on cooling; the crystals shoot in thin rhombic plates and frequently diverge like a fan; they form a beautiful group in the midst of the blue fluid, and the latter may be turned off so as to leave them, after drying by bibulous paper nearly pure.‡ The salt may then be decomposed by heat and the pure silver obtained; the fluid contains nitrate of silver with nitrate of copper.

(d.) *Not deliquescent, soluble§ in 4 parts of cold water, and in less of boiling.*

(e.) *Composition, oxide of silver 1 equiv. 118 + 1 equiv. of acid 54 = 172 its equivalent.*

(f.) *Fused by a moderate heat, it loses not over 1 per cent. by parting with water, and when cast in oiled moulds it forms the lunar|| caustic of the shops which is very convenient for chemical experiments, as it enables us to give nearly every illustration of the properties of the salts of silver. It is prepared, by evaporating the solution and casting it in moulds, without previous crystallization.*

the action is violent, some of the silver is carried over by the fumes, as appears from the white precipitate which they produce when passed through a solution of salt or muriatic acid.

* Dissolve 2 drachms of pure lunar caustic and 1 of gum arabic, in 7 drachms of pure water and add a little China ink; this is contained in one of the small vials; of which two are usually put up in one case; the other vial contains sub-carbonate of soda dissolved in the proportion of 2 oz. with 2 dr. of gum arabic, in 4 oz. of water; (Quart. Jour. XXII, 407.) with this we first moisten the surface, and then write with the other, which is nitrate of silver; the alkali precipitates the oxide of silver which is soon blackened by the light, and forms a permanent union with the vegetable fibre; it is indelible by washing and by use, and perhaps it would not be easy to remove it by any agent that would not also injure the substance.

† With 80 parts of nitric acid, and 8 of pure silver, we obtain 13 of the nitrate; and 10 or 11, if the same weight of standard silver is used.

‡ The decanted fluid and the washings will of course be reserved as they are rich in silver which can be easily extracted.

§ Thénard says "soluble à peu près dans son poids de l'eau à 15° (59° Fah.) et dans moindre quantité d'eau bouillante."

|| Lunar, from the alchemical name of silver, (Luna,) and caustic from its activity in disorganizing the animal texture. It is the neatest and most convenient of all the escharotics and is frequently used.

(g.) *It deflagrates with ignited charcoal*; lay a fragment of the solid lunar caustic on a burning coal; it will burn vividly and become covered with silver, which may be melted into globules by the blow-pipe.

(h.) *It detonates with phosphorus* when smartly struck, and with sulphur, if the hammer be hot.

(i.) *If redissolved, it crystallizes anew*; the liquid nitrate is not decomposed by light, if in a close vial, but in the air it is decomposed by that agent which also blackens the crystals and the lunar caustic, to prevent which, the sticks of the latter are wrapped in paper.* Filters, through which nitrate of silver has been passed, become by keeping entirely black, with something of the argentine lustre.

(j.) *Heat totally decomposes the nitrate*, even without combustible matter; nitric oxide and other gases are given out, and silver remains.

(k.) A newly melted stick of phosphorus, if placed in a very dilute solution of the nitrate, is in half a day covered with minute dendritic crystals of metallic silver; the precipitate is dark and has no beauty.

(l.) *Hydrogen gas*, coming in contact with letters written with nitrate of silver, on a card, or with a figure made on a ribbon with the same solution, while still moist, revives the silver, and produces a pleasing appearance, which is however more striking with sulphuretted hydrogen gas.

(m.) Fresh burnt or newly ignited charcoal, soaked in distilled water, and aided by the sun's rays, or by the temperature of 212° precipitates the silver, in the metallic state, from the solution of the nitrate; the crystals in the sun's light, are white and brilliant, and those obtained by heat are like bright flattened wire.†

(n.) *Silver is precipitated* from the nitric solution by several metals: the precipitate by mercury has been called the *Arbor‡ Diana*.

(o.) The old process§ is unnecessarily complicated; all that is necessary is to drop a globule of mercury into a dilute solution of nitrate of silver; in a few hours it begins to shoot, and goes on augmenting for many days. With time and repose, it produces a beautiful mantle tree ornament; I have often obtained crystals an inch in length, and as large as a knitting needle, and innumerable needles, like threads or hairs, usually form a tangled thicket, next to the amalgam.

* A very minute quantity of vegetable or animal matter, separates metallic silver from this solution. Although perfectly metallic, this powder is nearly black.—A. A. H.

† Phil. Trans. Vol. 88. p. 460.

‡ From its dendritic appearance and from Diana one of the old names of silver, sometimes substituted for Luna.

§ The usual directions are; amalgamate by trituration, 1 part leaf silver, with 7 of mercury; put a piece as large as a bean, into a bottle, containing 6 drs. of saturated solution of nitrate of silver with 4 of a similar solution of mercury diluted with 5 oz. of pure water; repose and time, will produce a beautiful dendritic crystallization.

(p.) *Copper is the most common metallic precipitant of silver; it must be made clean and bright, which may be effected by scouring, or more easily and perfectly by immersing it in aqua fortis of common strength, and at the moment when action commences all over the surface, it must be withdrawn and plunged into water and then wiped dry. In this state, on immersing it in a solution of the nitrate,* it will be instantly covered with a beautiful metallic grove of white crystals of silver. A bright cent or a copper rod may be used in this experiment. The silver obtained in this way, after being thoroughly washed, is regarded as pure or very nearly so, and this method is used both in analysis and in the arts.*

(q.) *The nitrate is decomposed by alkalies and earths, and by their soluble carbonates; the former give a gray, the latter a yellowish white precipitate; ammonia re-dissolves the precipitate and becomes fulminating; all the precipitates from the soluble salts of silver are blackened more or less by the light.*

(r.) *The sulphates, muriates and phosphates, and all salts whose acids form with silver an insoluble compound, decompose the nitrate, by double affinity.*

(s.) *A sub-nitrate is formed by boiling a solution of the nitrate, with silver, minutely divided; the solution is yellow and difficult to crystallize, but shoots into fine bladed crystals if nitric acid is added to it.†*

FULMINATING SILVER OF BERTHOLLET.

(a.) *By lime or barytic water, or even by potassa or soda, precipitate a concentrated solution of nitrate of silver, formed from silver that contains no copper; the precipitate will weigh rather more than the solid nitrate;edulcorate and dry the precipitate thoroughly; add the oxide in the proportion of 10 or 12 grs.‡ to about half an ounce of pure liquid caustic ammonia, perfectly free from carbonic acid; after remaining 10 or 12 hours, the powder becomes black, and in part falls, or is in part or entirely dissolved by the ammonia; the ammonia is poured off from the black powder, if there is any, and the ammoniacal solution is left to evaporate spontaneously; in 10 or 12 days a dark pellicle appears, which must be cautiously removed and left to dry in the air, in separate parcels of a grain or two, which must not be touched, after they are dry.*

* This is the method used in mints in the process of parting, as it is called; nitric acid separates silver from gold, which it does not dissolve, and then copper precipitates the silver in the metallic state. The whole of the silver is not recovered in this way, for a solution of salt will throw down a curdy precipitate from the fluid, after the precipitation of the copper has ceased; towards the last, a little copper goes down with the silver, but it may be separated by adding more nitrate of silver. The solution is of course nitrate of copper, and this forms verditer, when lime is added to it.

† For many curious particulars, see Nich. Jour. XV, 376, and Jour. de Physique, Tom. LXII, p. 219. ‡ Not more than 2 or 3 grs. should be prepared at a time.

(b.) *This fulminating powder is formed by heating together muriate or chloride of silver and pure ammonia, and adding fragments of caustic potash; when effervescence has ceased, the black fluid must be diluted and filtered and the black powder, on the filter, dried in the sun. Care must be taken whenever ammonia, especially if mixed with potassa and boiled, is brought into contact with the oxide of silver, as the fulminating compound is apt to be formed.*

(c.) *It is a most dangerous preparation, exploding by blood heat, by the touch of a tube or even sometimes of a feather; by concussion, produced by the explosion of a contiguous portion, and often without any known cause; it explodes even under the fluid in which it is formed, and of course while still wet.*

(d.) *It would seem to be composed simply of ammonia* and oxide of silver, and that the detonation must result chiefly from the action of the oxygen upon the hydrogen, forming steam, and this is suddenly disengaged along with the nitrogen and the metallic silver.*

(e.) *Attempts have been made to decompose it in a retort, by heat, and nitrogen gas has been obtained from it, but such experiments are extremely hazardous and should never be attempted, nor should the young chemist meddle at all with this preparation, which has caused several fatal accidents.*

DETONATING SILVER OF DESCOTILS.

Remark.—I have long prepared this dangerous compound by the following process,† which, in fifty trials, I have never known to fail, and it is simpler and easier than the original one of M. Descotils; I have met with only one accidental explosion, the cause of which I will presently state.

(a.) *Take 100 grs. of good lunar caustic, finely pulverized in a glass or Wedgwood mortar, taking care that the eyes are protected, and add 1 oz. of good alcohol and 1 of nitric or nitrous acid; if strong, there is an immediate action; otherwise a gentle heat may be applied till the action commences, but I always avoid the necessity of using heat, by preparing a strong nitrous acid; the gray powder, which is floated and agitated in the fluid by the gas that is evolved, is immediately converted into white flocculi, when we throw in water to arrest the operation; with good materials, it may be performed conveniently in a tumbler, standing in a dish to catch the reagents, should the glass break, and the whole should be placed under a vent. Alcohol may be used, instead of water, to check the action, or if added at first, by little and little, it may prolong it and increase the*

* Or possibly, as Dr. Ure suggests, of the oxide and nitrogen, in analogy with the chloride and iodide of nitrogen, but this seems hardly probable.

† First suggested, I believe, by an Italian chemist.

product; when added abundantly, it will stop the action as effectually as water. *Do not move or touch the vessel during the effervescence*, not until the water or alcohol has stopped the action entirely,* and proceed in every step with the utmost caution; *with pure cold water, edulcorate the precipitate* as it lies on the filter, and *dry it* either *in the air* or on a merely warm chalk stone;† I usually employ only 10 or 20, or at most 25 grains of the lunar caustic, and the alcohol and acid in proportion, that there may be the less danger in case of accident. The powder produced is more than half the weight of the lunar caustic employed; it is soluble in 36 parts of boiling water, and by cooling, it is obtained in crystals; it has a disagreeable taste and blackens the skin. The residual liquor and washings, contain some silver which may be separated by common salt.

(b.) *The original process of M. Descotils*, which is still substantially followed in the books, is to add alcohol to the solution of nitrate of silver, and apply heat while the silver and acid are still acting on each other; 40 grains of silver are dissolved in 2 oz. of strong nitric acid, with as much water; 2 oz. of alcohol are added, and the mixture heated, and 60 grs. of the fulminating powder are obtained.‡ From much experience in preparing this powder, I should, decidedly recommend the process under (a).

PROPERTIES.

(a.) *Highly explosive; managed with safety only in small quantities of a few grains; detonates by a heat above 260°; by the slightest pressure or friction; by electricity and galvanism; by sulphuric acid; by the spark from flint and steel received on a paper, or in a pistol pan, the touch hole being plugged with wood and the pan cautiously shut by pliers or forceps; § by a train of gunpowder with fulminating silver at one end; by contact of hot wire.* This fulminating powder, as well as that of mercury, is rendered much more energetic by being made thoroughly dry.

* Sometimes the portion of alcohol mentioned in the beginning of these directions is exhausted, and the fulminating silver, involved in red fumes, still bursting forth from the large bubbles that form and break in the bottom of the vessel, adheres to the glass in an almost dry state; this should always be prevented by adding more alcohol, because the fulminating silver may be decomposed, and perhaps exploded, by the heat generated in the finishing action of the acid.

† I refer the student to the directions given for the management of the fulminating mercury, p. 818 of this volume, only observing in this case, still more caution and dividing the powder into portions of 4 or 6 grains, which should be kept as there described and in a dark place; still, I find that in keeping around the year, the fulminating silver always turns superficially black, but its detonating powder does not appear to be materially injured; if there is a little pile of the powder, it remains white in the interior.

‡ Cruickshank's process mentioned by Henry.

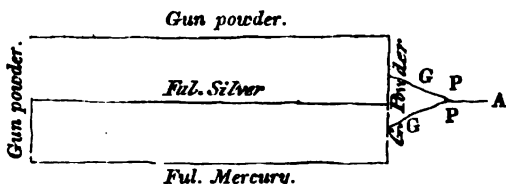
§ Not by the fingers; in my laboratory, an assistant had one of his fingers torn by shutting the pan in the usual way; some of the powder had doubtless lodged between the cheeks of the pan, and was exploded by the pressure.

(b.) *If, by a gentle movement with a feather, it is mixed with sand on a piece of writing paper, its irritability is much increased; if this mixture is laid on an anvil (not more than 1 grain at a time) it will not bear the weight of a hammer, or the slightest movement* between the contiguous surfaces, without a bright flash and a sharp detonation; the operator should take care of his eyes, for the sand is projected with so much force as to make the face tingle.*

Comparative experiments.—It would probably not be safe even to pour the fulminating silver into a hole in a block of wood, as is done with fulminating mercury, but we may compare the energy of these powders with each other, and with gun powder, by the following simple arrangement.

(c.) *Cut off three quills at the junction with the pith; stick the closed end in a mass of dough† placed on a board; fill one quill with gun powder, another with fulminating mercury, and the remaining one with fulminating silver; they may then be fired by a hot iron wire or ramrod; the gun powder will whizz, but without explosion, as from the touch hole of a cannon, while the other powders will explode violently, and the fulminating silver by far the most so.*

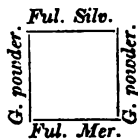
(d.) *Lay three parallel trains on a wide board so that they shall be a foot apart; at one end, connect the fulminating powders by a cross train of gun powder, and at the other end of the board, let the train of gun powder extend quite across, and terminate in branches, united in a common train, as in the figure; fire it at A; the train of fulminating silver will explode, without succession of time, although 3 or 4 feet long; the fulminating mercury will give an instantaneous flash and report, while the gun powder will burn with comparative slowness, and the portion at the remote end of the board will not be fired.*



* This account is, I am aware, very different from that given by M. Descotils (Ann. de Chimie, Vol. LXII, p. 198, and Nicholson's Journal, Vol. XVIII, p. 141.) who says, "that a blow or long continued friction causes it to inflame, with a brisk detonation. Pressure alone, if it be not very powerful has no effect upon it." I can account for this statement (so dangerous to young operators, and which has been ever since copied into the most respectable elementary treatises,) only by supposing that the powder might have contained a mixture of the nitrate precipitated by the alcohol, in consequence of its seizing the water of the solution, which sometimes happens in preparing the fulminating mercury, or that the precipitate was not dry; it is quite certain that the fulminating silver, when properly prepared and dry, will bear neither pressure nor friction, and very little, even when wet.

† Sand and moist clay are thrown about to a distance, to the annoyance of the spectators. If the quills are placed in holes in a board, the splinters are apt to fly, and I have found no support so good as dough.

(e.) The same thing is shewn by making a square thus, with opposite trains of gun powder, and of the two fulminating powders, one on each side; if either of the latter is fired, the gun powder will not catch; if either gun powder train is fired, both fulminating trains will explode, and the other gun powder train will be untouched.



(f.) The filters, from which the fulminates of silver and of mercury have been removed, still contain enough to explode when they are held* over burning coals or an ignited shovel; the report from both is remarkable, but from the silver it is deafening.

Composition of fulminating silver and mercury.—This has been elaborately examined by Liebig,† and by Liebig and Gay-Lussac,‡ but at present only the conclusions will be presented, and the subject will be mentioned again under Prussic acid.

(a.) M. Liebig has found, that these preparations are composed of the oxides of the metals, and a peculiar acid, called by him, the fulminic acid; that they are therefore true saline compounds and that the acid is identical with the cyanic acid, whose basis is cyanogen, and cyanogen is a compound of nitrogen 1 equiv. 14, and 2 of carbon 12=26 its equiv.§ This compound base, with oxygen, forms the acid in question; which is composed of cyanogen 1 equiv. 26, +1 equiv. of oxygen 8=34 its equiv.

(b.) The fulminating silver consists of 1 equiv. of oxide of silver 118 + 1 equiv. of cyanic acid 34=152 its equiv., and the fulminating mercury has a similar constitution, substituting oxide of mercury for oxide of silver.

(c.) The fulminic acid can be transferred from the silver to mercury, and to the alkaline bases, forming true fulminates, but in the latter case the salts are triple, consisting of the alkaline base, the oxide of silver and the fulminic acid.

(d.) The explosive powers of the fulminating silver, as was remarked with respect to the fulminating mercury, probably depend upon the mutual reaction of the elements, producing æriform bodies which are suddenly evolved, and their evolution is not improbably connected with electrical agency.||

* By tongs or some other instrument.

† Ann. de Ch. et de Ph., Vol. XXIV, p. 294. ‡ Id. Vol. XXV, p. 285.

§ See Vol. I, p. 417. See also Amer. Jour. Vol. XVIII, p. 337, where Dr. Ellet states the reasons for believing that the acid contains silver as an element, and the same view is extended to fulminating mercury.

|| Caution.—Although it is now sufficiently known, that the fulminating silver explodes, even while immersed in the fluids in which it is forming, it may not be superfluous to mention the following occurrence, the particulars of which are stated in Dr. Bruce's Min. Jour. Vol. I. In July, 1811, I was preparing the fulminating silver of Descotils, and the materials were in a small Wedgewood basin; there were, I think, about 50 grains of lunar caustic, the alcohol and acid were not the strongest, and a little

VIII. CHLORINE and *Muriatic acid*.

(a.) *Muriatic acid* has little or no action upon silver, but in a long time, especially with heat, a muriate or chloride, in small quantities is produced; silver connected with zinc, and immersed in the acid, becomes negative, and is then corroded with more rapidity.—H.

(b.) The chloride is instantly formed by mixing muriatic acid, or muriate of soda or any dissolved alkaline or earthy muriate, with any nitrate or other soluble form of silver, when an abundant curdy precipitate subsides.

(c.) *Muriatic acid* and *nitrate of silver* are, reciprocally, the best tests for each other; all natural waters (except rain and snow water) indicate muriatic acid by the test of nitrate of silver; even the thumb, used as a stopper in shaking a vessel of distilled water, imparts muriate of soda enough to be discovered by this test.*

Chloride of silver.†

According to the views at present entertained, there is no muriate of silver; muriatic acid, in contact with oxide of silver, becomes chlorine by giving its hydrogen to the oxygen of the oxide to form water, and the chlorine combines with the metal to form a chloride.

The white precipitate just mentioned, is now viewed as chloride.‡

PROPERTIES.

heat was used to induce the mutual action; I even ventured to take up the dish and look at the contents more nearly, and had this been all, it might have been well; but I presumed so far, trusting to the wet state of the mixture, as to touch with a glass rod, some of the solid materials that seemed to adhere to the bottom of the dish, and not to be in full action; they bore the slight pressure a number of times, but at last exploded with great violence; the dish was blown into innumerable fragments, none of which hit my face, but my head and eyes received a violent concussion, and the lunar caustic and nitric acid were blown into the latter, so that I was thrown into immediate blindness, and sustained great suffering, and a confinement of a month in dark rooms, with starvation and severe depletions of every kind to counteract the inflammation. I was so far favored, that the judicious measures of my physician (Dr. Eli Ives) were rendered successful, although it was necessary to separate, by violence, the eyelids from the eyeballs, between which an adhesion had commenced, and had begun to fix them in their sockets; I was partially salivated by the metallic fumes, proving that this effect is not confined to mercury, and I now record this accident (which might have been avoided, and was incurred by presumption, when the danger was not unknown) that others may act, as I have always done since, and had ever done before, with more caution.

Severe and even fatal accidents have too often occurred from the fulminating metallic powders. They are sometimes, very improperly, made subjects of amusement as is seen in the little crackers or torpedoes which explode upon being thrown upon the floor. (See Am. Jour. Vol. I, p. 168.) A twisted paper contains the fulminating silver mixed with sand to produce attrition, and to disguise the powder, and a lead shot, to give it momentum when it is thrown; still to a person unacquainted with the subject, the paper presents nothing to the eye but a shot and some sand with some minute white flocculi which might well escape the eye of a common observer.

* Some of the purer mountain waters, such as that of Lake George, N. Y. afford scarcely any indications of muriatic acid by this test.—J. G.

† Chloride of silver is found native.

Still, in familiar language it is usual to call the white curdy precipitate a muriate.

(a.) *A delicate test of light*; (see Vol. I. p. 41.) *even in diffuse light it is soon tarnished* of a purple or violet, and becomes eventually black.* Gay-Lussac thinks that this is owing to the disengagement of metallic silver, which remains when ammonia is made to dissolve the chloride.

(b.) *Fusion, by a gentle heat† just below redness, produces a gray, secile, tough, flexible, semi-transparent, hornlike substance*; ‡ *the old luna cornea*; by a higher heat it is reduced on charcoal.

(c.) *Composition*.—Silver, 1 equiv. 110, + 1 equiv. chlorine, 36 = 146 its equiv. 100 parts of silver give 133 of luna cornea.

(d.) *Absolutely insoluble in water*; *soluble with heat, in muriatic acid*, (and in no other,) from this solution octahedral crystals are obtained; the solution, if diluted with water, lets go the chloride.

(e.) *Soluble also in pure ammonia§ without decomposition*; evaporation by artificial heat gives, at first, crystals of fulminating oxide, which cause the mixture to detonate on the slightest motion; we should therefore be careful in managing mixtures of ammonia and chloride of silver.

(f.) *Chloride of silver is formed, in large quantities, in the process for purifying the metal*; the nitrate already described is formed from standard silver, and *decomposed by muriatic acid or by muriate of soda*; when the quantity is large the precipitate is most remarkable; it falls in masses as dense as cheese curd; it subsides more readily and perfectly than any other precipitate, and the fluid becomes clear as soon as the nitrate is all decomposed; the precipitate is washed abundantly and repeatedly, with boiling hot water, the masses being agitated and broken up to allow the water to penetrate.

(g.) *Even when there is no longer either color or taste in the washings, they may still contain copper*, and ammonia is the test for deciding this question; if it gives a blue solution, the washing must be again repeated, till ammonia ceases to produce any effect. The chloride may then be dried, and kept for use, the principal of which is to afford pure silver.

(h.) This is effected by fusing it in a crucible with 2 parts of caustic fixed alkali,|| or 3 or 4 parts of carbonate; a full forge heat is required to reduce it, and the silver is found at the bottom of the crucible.¶

* A small portion of vegetable or animal matter is said to hasten the discoloration.—J. G.

† A little of the muriate is volatilized in the heating.

‡ Supposed by some, to be the flexible glass presented to the Roman emperor Tiberius; it may be hammered, cut with a knife or scissors, and turned on the lathe; from a state of fusion it sometimes crystallizes in octahedra.

§ Several other white chlorides, as of lead, bismuth, &c. are insoluble in ammonia, which furnishes a means of separating them.

|| Or one fifth quick lime, and one twentieth of charcoal powder.

¶ Having repeatedly reduced silver in this manner, on a considerable scale, to afford silver for chemical vessels, I have never discovered any copper in it after its purification.

(i.) The following process of Arfwedson is recommended by Thénard.* Place the *moist chloride in a basin with zinc filings and diluted sulphuric acid*; the hydrogen evolved from the decomposition of the water *detaches the chlorine from the silver, and liberates the latter*, which remains in the form of a powder. By trituration, when moist, with zinc filings, it becomes hot and melts into an alloy.†

(j.) *Chlorine gas if warm, burns silver leaf*, producing a chloride, exactly resembling that which is made by precipitation, as stated above.

(k.) *A chlorate may be formed by passing chlorine gas through water in which oxide of silver is mechanically suspended*; or by adding the latter, when recently precipitated, to chloric acid;

(l.) Or, by digesting chlorate of alumina (formed by passing the chlorine gas through alumina suspended in water,) with phosphate of silver, made by mingling phosphate of soda and nitrate of silver.

Properties.

(m.) *Soluble in 2 parts of hot water*; on cooling, *gives white rhomboidal crystals*; soluble in alcohol; fused and decomposed by heat, giving out oxygen gas, and leaving a chloride; by percussion on an anvil,‡ with half its weight of sulphur, it detonates violently.

Other Argentine salts.

Carbonic acid.—No action on silver or its oxide; a carbonate is however easily formed by decomposing the nitrate of silver by a carbonated alkali; this precipitate, which is yellowish white and blackens in the light is easily dissolved in almost any acid, and is in a convenient form for keeping silver for solution or combination. At the end of a year it is found partially decomposed and contains some metallic silver.

(a.) Generally, *the other salts of silver are formed by digesting the acid on carbonate, or oxide of silver*, or by mixing a solution of a salt containing the acid, with one of nitrate of silver.

(b.) *Acetate of silver is formed, by mixing acetate of potash and nitrate of silver*, or by digesting acetic acid on the carbonate; it crystallizes from its hot solution; is decomposed by light, giving metallic silver, and is of use in separating nitrates and muriates.

Cheap solvent of silver.§

Nitre 1 + 8 or 10 strong|| sulphuric acid, a very useful solvent, to recover silver from old plated goods; with a heat between 100° and 200° it dissolves $\frac{1}{2}$ or $\frac{1}{4}$ of silver without touching copper, gold, lead, or iron; the silver is precipitated by copper, after dilution, or by

* Vol. III. p. 381 5th. Ed.

† Faraday, Quar. Jour. VIII. 374.

‡ See Chenevix's Memoir. Phil. Trans. 1802.

§ Nicholson's and Aikins' Dictionary, and Philos. Trans., Vol. 80.

|| If diluted, it will dissolve the copper, and in its concentrated state it dissolves some tin and mercury.

muriate of soda, and in the latter case it is recovered in the usual way by fusion with alkalis. *Ferro Prussiates precipitate silver white, becoming blue*; the prussic acid gives a white precipitate like the chloride.

Chromate of silver is formed by mingling chromate of potassa with nitrate of silver; it is of a dark purple or carmine red. A bichromate of a deep red color, like native red silver, and crystallized in a doubly oblique prism was obtained by spontaneous evaporation, from the fluid remaining from the precipitation of nitrate of silver by chromate of potassa, the precipitate being removed.*

IX. IODINE.—*Iodide of silver is formed by heating iodine with the metal or better by adding hydriodate of potassa or hydriodic acid, to solution of the nitrate.* It is greenish yellow, insoluble in water, and in ammonia, decomposable by potassa with heat, and composed of 1 equiv. of iodine, 125 + 1 of silver 110 = 235 its equiv.

X. ALLOYS.—*Silver unites with all the metals except nickel.*

1. Copper† 1, and silver 11, form the standard silver of Great Britain;‡ in the United States§ the silver coin is composed of silver 1485 to copper 179, so that the copper is about one ninth: in France, silver 9, and copper 1; *this alloy being harder and firmer than silver, wears longer, and receives a more perfect impression in coinage.* It is still very malleable and ductile.

The silver utensils and ornaments are generally made of standard silver, and are fashioned by hammering, as silver does not cast well; handles and other irregular parts are put on by soldering, and the beauty of fine silver is given to the surface, by boiling the silver in a copper vessel containing very dilute sulphuric acid, which dissolves out the copper of the alloy and leaves the silver of a dead white; it is then burnished and exhibits its proper beauty of color and lustre. A finer silver is employed for silver wire and leaf, which require more softness. In France, they formerly used an alloy of 4 copper, and 1 silver, under the name of *monnaie de billon*; it is now disused for coin; silver utensils in that country are composed of $9\frac{1}{2}$ silver and $\frac{1}{2}$ a part of copper; trinkets of 8 silver and 2 copper; silver solder is composed of 6 or 7 parts of silver, and 3 or 4 of copper.—*Thénard.*

* Phil. Mag. et Ann. Vol. I. p. 345.

† Nicholson (Dict. Art. silver,) asserts that the standard is 15 silver to 1 copper. Ure's revision of the same work says 12 1-2 silver to 1 copper. Dr. Henry states 11.10 of silver to .90 copper; 1 lb. standard silver is coined into 66 shillings.

‡ Silver of commerce in Great Britain contains 37 of fine silver and 3 of copper, or 9.78 per cent. of copper. The fine silver obtained by cupellation often contains some gold; after solution in nitric acid, the gold is left either a purple protoxide or black peroxide.

§ 1 dollar contains 416 grs. of standard silver, of which 44 are alloy; the Troy pound contains 10 oz. 14 dwts. $4\frac{5}{8}$ grs. of fine silver, and 1 oz. 5 dwts. $19\frac{2}{3}$ grs. of alloy, and is coined into $13\frac{1}{3}$ dollars; or 13 oz. standard silver are coined into 15 dollars.—*Webster.*

Silver and copper in equal parts, with 4 or 5 of arsenic, form a white and still malleable metal.

2. *Lead and silver unite apparently in every proportion*, and as the silver predominates, the alloy is harder, whiter, and less fusible than pure lead. With lead 7, and silver 1, the alloy is greyish white, and less ductile than either of the metals. Upon the attraction between silver and lead and copper, are founded the processes of cupellation and eliquation.

3. *Iron has little disposition to unite with silver*, and yet I have found on melting silver in an iron ladle, that there was a firm adhesion of globules of silver to the iron.* We have already mentioned (p. 275) the alloy of steel and silver.

4. *Zinc, bismuth, antimony*, and some other brittle metals *form with silver, brittle alloys* of little importance.

5. *Tin and silver produce an alloy* whose malleability is less than that of the metals that compose it.

6. *Mercury unites with silver in every proportion*, and heat is disengaged during the combination. Silver leaf, rubbed in the hands with quicksilver, immediately forms an amalgam which is soft, pasty, or fluid, according to the proportions. With 1 part of silver, and 8 of mercury, the amalgam is soft, very fusible, and crystallizes easily: it is made by throwing silver filings in portions, 1 part into 12 or 15 parts of mercury, heated to about 400° Fah. and straining it through chamois leather. A silver coin, dropped upon a basin of mercury is immediately amalgamated, and if worn in the pocket among other coins of silver or gold, their surfaces will, in a short time, be covered with mercury.

XI. MISCELLANEOUS.

1. EARTHS.—*The oxide of silver tinges earthy matters yellow.*

2. *Purification in the arts.*

(a.) *Silver is scorified with nitre; or heated in thin plates with black oxide of manganese*, and then mixed with 3 times its bulk of pounded green glass and melted.

3. ART OF SILVERING.

(a.) *Both for beauty and utility, copper and brass are often covered by silver; but iron more rarely.* There are five methods of silvering.†

1. *By amalgamation.*—Silver, precipitated from the nitrate by copper, is washed and dried; $\frac{1}{2}$ an oz. of this is mixed with 2 oz. of common salt, 2 of sal ammoniac, and 1 drachm of corrosive sublimate; they are rubbed together and made into a paste with a little water; the vessel is cleaned with dilute aquafortis or by boiling with a mixture of common salt and tartar; it is rubbed with the paste till it is

* For a curious fact on this subject see Ann de Chim. T. XXXIX, p. 265, and Aikins' Dict. Vol. II. p. 324.

† Aikins, Vol. I, p. 324.

covered with a white metallic coat which is an amalgam of the silver and quicksilver; it is washed, and dried, and heated nearly red, to volatilize the mercury, and lastly the silver is burnished.

2. *By luna cornea or chloride of silver; mix 1 part, with 3 of pearl ashes*, 1 of whiting, and a little more than 1 of salt; rub the surface with a piece of an old hat or rotten stone; moisten it with salt and water, rub on some of the composition with the finger; then wash, and rub it dry with a soft rag; this silvering is imperfect, and is commonly protected by varnish; it is used for dial plates of clocks, scales of barometers, &c.

3. *By silver in substance*.—Copper may be silvered by rubbing its clean surface with 2 drachms of tartar, 2 of salt, $\frac{1}{2}$ dr. of alum and 15 or 30 grs. of precipitated silver; rub the surface with leather to polish it.

French plating.—Burnish down upon the copper successive layers of leaf silver, to the desired thickness; the silver is solid, but the process is tedious, and the joinings cannot always be concealed.

Birmingham plating.—An ingot of copper is rendered smooth and clean, and sprinkled over with glass of borax; a plate of fine silver, one twelfth as heavy as the copper, is laid on, bound with wire, and heated red hot; it is next passed through the rolling press and extended at pleasure. 1 oz. of silver is frequently rolled out so as to cover 3 square feet, and its thickness is about $\frac{1}{33\frac{1}{3}}$ th of an inch. This kind of plating is used for the bands on the wheels of carriages, and it is the material of most of the silver-plated ware, such as candlesticks, tea-pots, &c. The covering is perfect but thin, and soon wears off at the edges and angles.

4. There is still *another process*, which is particularly useful in plating iron work for pleasure carriages. The silver is scorified by nitre and heated with charcoal; it is then cast in ingots, rolled, annealed, and rolled again; cut up into smaller pieces and again annealed, and rolled, &c., till it is sufficiently thin. The iron is filed bright, then wet with sal ammoniac solution, covered with rosin, and dipped in a bath of 2 parts tin and 1 lead; it comes out tinned; then the film of silver is applied, heated and battered down with a hammer covered by list, and rubbed with a heated soldering iron; the edges are cut to adapt them to each other; heat is then again applied in the fire, to unite the silver to the iron, by means of the solder; it is next rubbed with a steel rubber,* and cleaned with pumice and rotten stone. In this manner silver is laid on as covering, thicker or thinner, as may be desired, upon iron of any form.

XII. NATURAL HISTORY.—The proper ores of silver are, 1. Native silver. 2. Alloys of silver with arsenic, antimony or mercury,

* Made from a file, whose teeth have been removed by grinding.

including the antimonial and arsenical ores and the native amalgam. 3. Sulphurets, including the vitreous or gray silver, both the brittle and the sectile or soft, and the ruby silver, or sulphuret that contains antimony and other metals. 4. Chloride. 5. Carbonate. The most valuable of these ores are, the native silver, the arsenical and antimonial silver, and the sulphurets. There are, however, many other ores that contain silver, in sufficient proportion to admit of profitable extraction, and among these, the sulphurets of lead and copper are the most important.

XIII. ASSAY AND EXTRACTION.—The commercial value of silver is so great that it is extracted from the ores of other metals, even when it exists only in a very small proportion; the processes are so exceedingly various, and often complicated and difficult, that it is quite impossible to give even an outline of them, consistently with the nature and limits of the present work. Only a few particulars can be mentioned, but ample information may be found in various works.*

Assay.—Trial by reagents.—With respect to the proper ores of silver, (at least, if tolerably rich), there is generally no difficulty in distinguishing them by their sensible properties, and they will give up their silver to reagents and to the blowpipe flame. Most of the silver of Europe is obtained from the ores of other metals, and the question whether silver exists in any ore is easily settled by the following trial.

(a.) Roast the ore to expel sulphur, arsenic or antimony; dissolve every thing soluble in diluted nitric acid, aided by a moderate heat; all the metals that may be expected to be present, (except gold) will be dissolved, e. g. lead, copper, iron, &c. Then a solution of common salt, leaving the other metals, (except lead,†) will precipitate the silver, as a white chloride, which, being washed with boiling hot water, to dissolve chloride of lead, and then being dried and collected, will denote the proportion of silver, by its weight and known constitution, allowing about 75 per cent. for the pure silver. It is easily reduced by fusion with a fixed alkali, either by the blowpipe or in the crucible; the blowpipe alone will partially reduce the chloride, on ignited charcoal, but better with the addition of carbonate of soda.

(b.) From the above nitric solution of the ore, if it be tolerably rich in silver and there be no great excess of nitric acid, a slip of bright metallic copper will precipitate the silver, in the metallic state;

* Aikins' Dict. Art. Assay and Silver; Gray's Op. Chem. Art. Silver, with plates; Thénard's Chemistry; Humboldt's Essay, &c. on New Spain; and among the journals of science, the Annales des Mines.

† Mercury may be precipitated, but it is not likely to be present; if it were, it might be volatilized, either at first, in roasting, or out of the precipitate, in which if it existed, it would be in the state of calomel.

but the test, by salt, is more delicate, and might detect silver where the other would fail.*

Trial by the furnace.—This, in the small way, is generally done by cupellation, for a notice of which see this volume, p. 253. Amalgamation may also be used, but this is generally resorted to in the large way.

2. *Extraction in the large way.*—For an account of these processes, recourse must be had to the large works on metallurgy. We can make only two or three statements.

(a.) Native silver needs only fusion, and heating to a sufficient degree, to expel arsenic or antimony; if it contains gold or other metals that are not volatile, the fact will be ascertained by the chemist or the assay-master at the mint, and the silver will receive the alloy of copper to fit it for coin, utensils, &c.

(b.) Most of the other ores of silver are subjected either to cupellation or amalgamation. Lead has so strong an affinity for silver that, by fusion, with proper additions, it is thus extracted from most ores, and it is afterwards separated from the silver, (along with other baser metals,) by cupellation.†

(c.) *Amalgamation* is extensively employed in Europe, and almost exclusively in Peru and Mexico. The ores are ground fine, moistened and mixed with 2 or 3 per cent. of common salt; the mass remains for some days and is then mixed with lime, and with roasted iron and copper pyrites; it is now again allowed to repose for some days, when the mercury is added and trodden in by men, or by horses and mules; more lime, roasted pyrites and mercury, are added from time to time, and after some months, the combination of the mercury and silver having taken place, every thing that can be dissolved or removed by abundance of water is got rid of in that way, and lastly, the mercury is driven off by heat and mostly saved by a rude distillation per descensum,‡ and answers for subsequent operations. The greater part of the quicksilver of commerce is used for these and similar purposes.

Remarks.—I have had occasion to examine, by cupellation or in the moist way, several galenas of this country, and have found them, generally, argentiferous. That from the mine of Ephraim Lane, (Munroe, Conn. 17 miles west of New Haven,) I found to contain $3\frac{1}{2}$ per cent. of silver, or 272 oz. to the ton of reduced lead; and a sulphate of lead which accompanies it is stated to be equally rich; the silver is found in profitable quantity also in the midst of the blende,

* I once obtained, in this way, an abundant precipitate of silver from the nitric solution of a pyritical ore, but as it was brought to me *pulverized*, I supposed that the silver had been fraudulently introduced.

† When lead is used to extract silver from copper, the process is called eliquation.

‡ For drawings of the apparatus, see Gray's Operative Chemist.

which is abundant in the same mine, and appears to contain the argentiferous galena, in intimate mixture. Lead from Bethlem, Conn. gave me 6 oz. to the ton; that of Southampton, Mass. gave $12\frac{1}{2}$ oz. to the ton, (which in Great Britain would just pay the expense of extraction;) that of Missouri gave only a trace. As we have, in the United States, so far as we are informed, no proper mines of silver, we ought to attend to our argentiferous galenas, of which there can be no doubt we have abundance, and none hitherto examined appears so worthy of being wrought as that of Munro, (Lane's) which yields more than the richest argentiferous galenas of Europe.* For the statistics of silver, see Humboldt's New Spain. The quantity of silver annually obtained from the mines of Europe and America, is stated to be about eight hundred and fifty tons, and Europe does not produce more than one twelfth or fifteenth part of this amount.

XIV. POLARITY.—*Electro-positive*, like the other metals.

SEC. XXXV.—GOLD.

I. HISTORY AND NAME.—*No history or tradition reaches farther back than the knowledge of gold*: as it occurs in the metallic state, it is probable that it was observed as soon as the earth was peopled, and nations† have been found familiarly acquainted with gold and silver, when they were ignorant of iron. The Latin name is aurum, the Greek is χρυσός; the alchemical, Sol;‡ the allusion is evident; as the sun is among the stars, so is gold among the metals; to fabricate it, was the ultimum of the hopes of the alchemists. It has ever been regarded as the most valuable of natural bodies; its beauty and its fine physical properties (obvious before its chemical qualities were known) give it great intrinsic value, and among all nations a given weight of it represents, and will command more property, than the same weight of any other body.§

II. PROPERTIES.

(a.) *The only yellow simple metal*; it is orange or reddish yellow; when in fusion bluish green; in lustre inferior only to steel, platinum, silver and mercury.||

(b.) *Gold leaf appears green by transmitted light*, this is well seen when it is laid on a plate of colorless glass; it is easily done by moistening a glass plate¶ and lifting gold leaf from the book, by touching it at one edge with a moistened glass rod; it may then be laid smoothly on the glass, beginning at the disengaged edge of the hanging leaf.

* See Am. Jour. Vol. III, p. 176.

† As the Peruvians and Mexicans when first discovered by the Spaniards.

‡ Or king of the metals; hence its solvent was *aqua regia*.

§ Excepting a few rare chemical and medicinal preparations and minerals which sometimes, weight for weight, exceed gold in value.

|| When fused with borax, the color is paler; when with nitre it is brighter than common; to obtain a proper shade, a mixture of both is used by the goldsmiths.

¶ Saliva from the tongue is the best.

Gold is the only metal that transmits any light; this (p. 103 of this volume.) is doubtless owing to its thinness derived from its great malleability.

(c.) *Sp. gr.* about 19.3; authors give it from 18.75 to 20, it varies with the accuracy of instruments and manipulations, with impurities, compression, mode of casting, temperature, &c.; it is the heaviest body known after platinum.*

(d.) *In hardness, below silver, but above copper; differs not much from tin, (Davy); very flexible and tough; broken with much difficulty, and both terminations are wedge-shaped.*

(e.) *Receives the impression of the die very perfectly, clogs the teeth of a file, receives great brilliancy from the burnisher, but not from powders.*

(f.) *In tenacity inferior to iron, copper, and platinum, and much like silver; wire $\frac{1}{8}$ of an inch in diameter, sustains 254 lbs. one of $\frac{7}{8}$ ths. or $\frac{1}{3}$ th. of an inch sustains 150 lbs.*

(g.) *Malleability seen in gold leaf, this is prepared by beating very pure laminated or thin rolled plates of gold, between layers of animal membrane.†*

(h.) *Thinness of the leaf (Aikins) $\frac{1}{100000}$ th‡ of an inch; 3 grs. or $\frac{1}{100}$ of copper are added to the oz. and when old skins are used, even 12 grs. or $\frac{1}{4}$, to harden the gold.*

(i.) *No substance is capable of such astonishing extension as gold, as the following statements, derived from the best authorities, will shew. One grain of gold is extended, in gold leaf, to above 56 square inches, but much farther in gold wire, which is silver wire, gilded. 1 oz. of gold on wire can be extended more than 1300 miles; 1 gr. of gold covers 295 feet in length, and can be made to cover even 345.6; when the wire is flattened, the surface occupied by 1 gr. is 98.7 sq. in. and the thickness is only $\frac{1}{100000}$ of an inch§ still, with this extreme thinness, no part of the silver below is visible.*

(j.) *1 grain of gold is easily divided into 2,000,000 parts, 1 cub. in. into 9.523,809,523 parts, each distinctly visible; 1 grain can be*

* 19.257, Thénard.—19.2 to 19.36, Murray.—19.3 to 19.4, Laugier.—19.3, Henry. Average 19.32. In the ingot 19.207; when hammered, (Ellicott), 19.376 at 55° Fahr. Lewis, 19.358 in ingot; 19.361, hammered, Brisson.

† Strangers are not often admitted into the rooms of the gold beaters, because as I have had an opportunity of observing the slightest movements, even of the air, disturb these delicate operations. The gold after being forged, is rolled out till it is very thin, and then it is cut up into pieces of convenient size; it is again forged and annealed, and then hammered between layers of vellum, enclosed in parchment; the extended pieces are divided and again hammered between layers of animal membrane, (the prepared rectum of the ox) they are again cut by a cane knife, and again hammered and so on till they are thin enough. They are finally cut by a cane instrument, and by the aid of the breath, the leaves, of which there are 25, are then laid in the book, the paper of which is rubbed with ochre or bole, to prevent adhesion; this and other delicate operations are performed by females. For a more minute account see Aikins' Dict. Vol. 1 530.

‡ Nich. and others.

§ Dr. Hally, quoted by Aikins.

beaten into 50 leaves, each 1 inch square; these, divided by parallel lines, at 100th of an inch distance, and by others at right angles, produce 25,000,000, little squares, each visible without glasses; * 16 oz. of gold, if in the form of a cube, would not measure over $1\frac{1}{2}$ inch on each side, but would gild a silver wire long enough to encircle the earth.

(k.) *Dr. Black*, to enable us to form some clear conceptions, in a case when the mind conceives more clearly by comparison, remarks, that 14,000,000 films of gold, like that on some gold wire would not equal more than 1 inch in thickness, and that 14,000,000 thicknesses of common writing paper would equal almost $\frac{1}{2}$ of a mile. In gilding by amalgamation, gold is only $\frac{1}{100000}$ th of an inch in thickness, and yet the covering is perfect.†

(l.) Gold can be drawn into wire, whose diameter does not exceed $\frac{1}{10000}$ part of an inch.

(m.) These statements are sufficient to shew that no palpable substance comes so near to realizing the actual and physical divisibility of matter to an infinite or rather indefinite degree, as gold.‡

(n.) Gold melts at 1300°F .; that is a little above a full red heat; in small experiments, it melts easily by the mouth blowpipe, and in larger quantities in the forge fire; when melted, it appears of a luminous bluish color.

(o.) It expands but little by heat while solid, but more than any other metal on melting; hence it is bad for casting in moulds and brittle if suddenly cooled.

(p.) Its finely divided parts, when in fusion, do not unite easily without the aid of borax.

(q.) Crystallizes in octahedra if slowly cooled; in tetrahedral prisms, if the fluid part be poured out when it is congealing. It occurs natively crystallized.

(r.) Very fixed in the fire; no vapor rises from it when merely melted. Kunkel kept a quantity of gold almost thirty weeks in fusion, in a glass house furnace, without losing a grain, and without any alteration.|| It lost no weight after exposure for some hours to Parker's great burning lens.

* Boyle and Black.

† Note Book.

‡ Perhaps the only instance in which that which is certainly known to be matter is obviously more divided than gold is capable of being, is in the case of odors, which often and for a length of time, fill a great sphere with emanations, diffused somewhat in the manner of radiation. The matter of malaria is probably divided in a similar manner.

§ It is usually stated to be 32° of W. but this corresponds to 5237° of Fahr. which must be erroneous, as gold melts with a full red heat; 32° of W. do not correspond with 1300° of Fahr. as usually stated; 2° of W. would correspond very nearly with the truth, for $2^{\circ}\text{W.} = 260^{\circ}\text{F.} + 1077\text{F. for the } 0\text{ of W.} = 1337^{\circ}\text{F. Vol. I, p. 62.}$

|| Silver in the same place and time lost 1-12 of its weight, at another time 1-60, at another nothing.

(s.) *Volatilized by the solar focus*, and by the heat produced by oxygen gas directed upon burning charcoal; the vapor which then rises will gild a plate of silver held five or six inches above; volatilized also by electricity and galvanism, and by the compound blowpipe.

III. RELATION TO OXYGEN.

(a.) *Not oxidized under any common circumstances*; it may be kept for ages exposed to heat, air and moisture without any change.

(b.) *Converted into a purple substance*, supposed to be an oxide, by a powerful electric discharge through gold wire or leaf laid between plates of glass, or between papers, which will be found, stained purple. When the discharge is taken in a tube-containing the gold, the air is deprived of a part of its oxygen.*

(c.) *By the galvanic discharge, gold leaf burns brilliantly* with a red light, and is dissipated either in a state of division or of purple oxide.

(d.) *It burns also under the compound blowpipe*; the standard gold gives a green flame owing to the copper, as in the case of silver, (p. 330,) this is most conspicuous when the hydrogen flows with the oxygen; if it be shut off, the gold, particularly if pure, still burns with intense yellow light, but with little flame. The current of gas sensibly indents the melted globule, as I have often observed with respect to silver and other metals, when in fusion in the focus of the compound blowpipe.

(e.) *By this instrument, the gold is dissipated, apparently, in the state of oxide*, but I am not aware that it has been collected and examined.

(f.) If minutely divided by grinding gold leaf with powders, as chalk, calcined hartshorn, sulphate of potassa, &c. it is oxidized, by a heat, even below redness, if long† continued.

Nitre, with ignition, partially oxidizes gold, contrary to former opinions on the subject.

OXIDE.—*There is still considerable uncertainty respecting the relations of gold to oxygen*, although the subject has been elaborately examined by some of the most eminent chemists‡ whose memoirs are cited in the notes. Several of them I have attentively studied, but it is impossible to discuss the subject here, and we can give only those results which appear to be the best established. Gold is certainly in some way, oxidized, because the oxides are, without addition, decomposed by a melting heat, oxygen gas is obtained, and metallic

* This observation is not my own, and having omitted to cite the authority, I cannot recollect it; if the statement is accurate, it decides the question as to two oxides of gold.

† 16 or 20 hours, Lewis.

‡ See Vauquelin, Ann. de Chim. LXXVII, 321. Oberkampf, Id. LXXX, p. 140. Berzelius, LXXXVII, p. 114. Pelletier, Ann. de Ch. et de Ph. Vol. XV, p. 118. Javal, Id. Vol. XVII, p. 337. Thomson, Edin. Phil. Trans. 1827.

X gold remains. *We are certain of the existence of one oxide of gold and a second is highly probable*; the purple appears to be produced in all cases of the combustion of gold and the yellow or brown from its solution in nitro-muriatic acid. In all our experimental illustrations in courses of instruction, the phenomena are most satisfactorily explained upon the supposition of two oxides. It will be most convenient to mention, first, the oxide whose existence is fully established.

Yellow or brown oxide—peroxide.

As it is obtained by decomposing the muriate (or chloride) of gold only its properties will be briefly mentioned here, and other facts will be added under the muriate or chloride.

Properties.

(a.) *Color, after being dried in the state of hydrate, reddish brown*; insoluble in water; *little disposed to unite with acids*, but more readily combines with alkalis;* as has been already said, its oxygen is expelled by heat alone, and it is withdrawn by combustibles with great ease, and at a low temperature, frequently with the disengagement of much light. Muriatic acid readily dissolves it, forming the usual solution of gold, but it is observed by Pelletier, that it forms no definite compound with any acid containing oxygen.

6. *Composition.*—According to Oberkampf, 100 parts of gold combine in this oxide with 10.01 of oxygen; Berzelius, 12.077; Pelletier, 10.03; Javal, 11.909. The proportions rest therefore between 10 or 12 parts of oxygen in addition to 100 of gold. If, the gold being 100, the number 112† be regarded as representing the proportions of metal and oxygen in the peroxide, and if (according to Berzelius and Thomson) it contains three equivalents of oxygen, the equivalent of gold will be 200, and that of its peroxide (or of its oxide if there is only one) will be 224. It seems probable that this is the composition of the yellow or brown oxide, obtained from the muriate; but till we can decide whether the purple oxide (so called) is really an oxide or only minutely divided gold, we are in no condition to assign its proportion of oxygen. It may be 1 equiv., which would make its representative number 208,‡ and then there would be room for a deutoxide whose equivalent would of course be 216. On the whole, although it appears extremely probable that there is a purple oxide, we are absolutely sure of only one oxide, namely, the yellow or brown,

* Therefore Pelletier is strongly disposed to rank it as an acid, and calls it the auric acid, and the compounds aurates, but, as appears to me, without sufficient reason; see remarks under silica, Vol. I, p. 276.

† This number, so near that obtained by Berzelius (12.077), has been recently confirmed (as already stated) by Javal, who obtained 11.909. See his excellent memoir, *Ann. de Ch. et de Ph.* Vol. XVII, p. 387.

‡ Berzelius thinks that the purple oxide is a deutoxide, and of course its equiv. would be 216. He obtains, by potassa, from the protochloride of gold, a green precipitate, which he regards as a protoxide.

and its composition may be considered as 100 gold and 12 oxygen, or 200 gold and 24 oxygen, which are in the same proportion.

IV. ACIDS.

(a.) *Gold is attacked vigorously by no acid except the nitro muriatic; feebly by the fuming nitrous acid.*

(b.) *It is not affected by the pure and colorless nitric acid, but if highly charged with nitric oxide gas, and digested on gold leaf in a close vessel, the metal is readily taken up; but it quickly and entirely separates if the fluid be agitated in a vial with the included air, and both heat and light separate the gold in the metallic state.*

(c.) *Nitro muriatic acid is the proper solvent; this is the aqua regia of the ancient chemists. It has been usual to prescribe 2 parts strong nitric acid to 1 muriatic.**

This proportion of nitric acid is much too large; equal parts of the acids are better.† Proust‡ prefers 4 muriatic to 1 nitric, and this accords with my own experience, beginning with equal measures of the two acids, and adding more muriatic acid from time to time; it is not an easy thing to obtain a good solution of gold. Fuming nitrous acid, (prepared as at p. 447, Vol. I,) is the best, and the more highly charged with nitric oxide gas, the better does it act in nitro-muriatic acid.

When the action becomes languid, the addition of a little alcohol or ether renews it, and muriatic acid has the same effect.

(d.) *The following is a good process for the solution of gold.§* Provide a tubulated retort and receiver of glass; granulated or laminated gold 1 part, and 6 parts of nitric acid; warm the retort by a lamp or burning charcoal; add a little muriatic acid, which will produce a brisk action, and much nitric oxide gas and chlorine will be evolved; when the action is diminished, add more muriatic acid, and so on, until the solution is finished; raise the heat to distil over any remaining nitric acid; it comes pure till towards the last, when a little muriatic acid also rises in white fumes; thus there is no loss of acid, and solution of pure muriate of gold remains.||

CHLORINE gas, if warm, sets fire to gold leaf.

Gold dissolves, without effervescence, in the aqueous solution of chlorine.

* Or 1-2 part common salt or sal ammoniac.

† Diluted with an equal bulk of water, as most authors direct.

‡ Nicholson's Jour. Vol. XIV, p. 238.

§ Alkins, Vol. I, p. 533.

|| This is a very judicious arrangement, and with good reagents, it always affords a rich solution of gold. I have succeeded best with strong acids without water, but there is always a portion of a yellow precipitate remaining, not soluble in hot or cold water, or in the acids; it is probably the insoluble proto-chloride which, by boiling with water, is converted into soluble per-chloride and metallic gold.—Turner.

Gold, in very thin laminae, being placed in a flask with 5 or 6 times its weight of water, is dissolved, by passing chlorine gas slowly* through it, at the common temperature; the solution is then concentrated.

This method is eligible for obtaining a solution of gold only because it *gives it without excess of acid*, but in practice, the nitro-muriatic acid is generally preferred.

Condition of the gold in the solution.

It appears to be uncertain whether this solution is a chloride or a muriate; if a chloride, it differs from most chlorides, which, by solution in water, become muriates; even the solution formed by passing chlorine gas through water containing metallic gold, may afford a muriate, as the elements of water may be divided between the chlorine and the gold. The action of the nitric or nitrous acid in effecting the solution of gold by the muriatic acid, may lie in decomposing the latter; its hydrogen being engaged by the oxygen of the nitric acid, and the liberated chlorine then uniting with the gold; but as we precipitate the latter from the solution by alkaline reagents, in the form of oxide of gold, it follows, either that the chloride of gold, immediately after it is formed, becomes a muriate by the decomposition of water, or that the same cause regenerated the muriatic acid and oxygenized the gold previous to the formation of the muriate, which was then formed as a consequence; (thus presenting a useless round of decompositions and recompositions,) or that oxygen was afforded to the gold and hydrogen to the chlorine at the instant of precipitation by an alkali; for in some way or another, the oxide of gold and muriatic acid are produced. If the student finds these alternatives perplexing, perhaps he will prefer the simpler view, namely, that the nitro-muriatic acid oxygenizes the gold by the agency of the oxygen derived from the nitric acid, and that the muriatic acid then unites with the oxide to form a muriate. Without pretending to decide this question, I shall, for convenience, treat the solution either as a muriate or as a chloride, as the phenomena seem to require, although high authorities treat it as a chloride only.†

MURIATE OF CHLORIDE OF GOLD.

Properties.

(a.) *The solution, as commonly obtained, is acid; its color is rich yellow;‡ very corrosive; taste strongly metallic and astringent*

* Bulle a bulle, Thénard.

† Pelletier and others.

‡ This yellow color depends on an excess of acid, for when this is neutralized or dissipated by a gentle heat, the solution becomes brownish red.

—*stains the flesh*, and most animal and vegetable bodies, of a deep purple; sinks into marble and produces a similar color.

(b.) *Slow evaporation and cooling give small yellow crystals*; tetrahedral prisms or 4 sided pyramids or truncated octahedra; they are obtained with more certainty, if, after evaporation, a little warm alcohol is added; these crystals* are viewed as a chloride or bi-chloride of gold, but since they contain water, *they may be equally well regarded as a muriate*.

(c.) *By a mild heat, they disengage muriatic acid and become*, at least in part, neutral and deep red; by a little additional heat, more acid and chlorine are liberated, and the compound is then regarded as a *proto- or sub-chloride*, which, by the action of water, becomes $\frac{1}{2}$ metallic gold and $\frac{3}{2}$ chloride; and by a still higher degree of heat, it is reduced to the metallic state; anhydrous acids produce no change upon it, but diluted acids convert it into metallic gold and chloride, the latter remaining in solution.

(d.) *The muriate in crystals (per-chloride) is deliquescent* and soluble in water without residue.

(e.) *Strong sulphuric acid precipitates* from the muriate of gold an *anhydrous chloride*.

(f.) *The muriate of gold is decomposed both by alkaline earths and their carbonates*, which give a yellow precipitate, becoming purple by exposure to the air, and reducible per se. Lime and baryta are better precipitants than potassa.

(g.) *Fixed alkalis throw down a brownish yellow sediment*. The solution should be diluted with 3 or 4 volumes of water, as *caustic alkalis are apt to redissolve the precipitate*; they should be poured in cautiously and only while there is a precipitate formed; if rapidly added, the liquor becomes slightly purple or greenish yellow; a blackish powder is precipitated, containing not over $\frac{1}{10}$ of the gold, and $\frac{9}{10}$ remain in solution† in the alkali, and several months elapse before the gold entirely separates.

(h.) *With a perfectly carbonated alkali and a little boiling, the whole precipitate appears at once*.

(i.) The alkalis appear to throw down part of the gold in the metallic state; for when muriatic acid is added, the oxide is redissolved, and the metallic gold is left untouched.

* No crystals are obtained if muriate of ammonia or of soda enter into the solvent. The *red lion* of the alchemists was a red colored fluid obtained in the receiver when the solution had been prepared in the retort by means of rough unsublimed sal-ammoniac; the heat is suddenly increased towards the end, when nearly the whole of the fluid has been distilled over; some very red muriate of gold rises.

† A compound of oxide of gold and potassa which Pelletier calls *aurate of potassa*; he supposes that the chlorine passes to the potassium to form chloride (muriate) of potassa, and the oxygen of the latter to the gold, to form oxide of that metal.

FULMINATING GOLD.*

A notice of this preparation is properly introduced here, as it results from the action of an alkaline reagent on the muriate of gold.

(a.) *The nitro-muriatic solution of gold is diluted with from 4 to 8 volumes of pure water; ammonia is added, drop by drop, till the precipitate, which is brownish yellow, ceases; it is thrown on a filter and washed in abundance of water, till every thing saline and acid is removed;† dry it in a warm room, without the direct application of heat; it weighs about $\frac{1}{4}$ more than the gold employed; if too much ammonia is added, a portion of the oxide is dissolved.‡*

(b.) *It may be prepared in any way by which ammonia is brought in contact with oxide of gold.§*

Properties.

(c.) *Not altered by keeping; explodes between 120° and 300° of F.; a few grains will beat a hole in a copper plate; it explodes also by a sharp stroke on an anvil,|| or by strong friction, and should not be kept in a ground stoppered vial,¶ but in a paper box; its detonating power is much increased by careful drying; it does not communicate from grain to grain, only the part pressed or heated being exploded; hence, we cannot fire it in a train.*

(d.) *It is conveniently exploded, by placing a few grains on a piece of sheet copper which may be laid on a ring and heated for a minute or two, by a lamp or candle; the report is very sharp with a flash, and if the copper is not torn, it is always indented.*

(e.) *It does not flash in a pistol pan; thrown upon burning coals or a hot shovel, it snaps and crackles, and in all places where it explodes, a cloud of the purple oxide of gold rises from it; the heated filter shews this strikingly; when held over the fire it explodes, not*

* Discovered by Berthollet.

† This I find to be very important to success; the preparation will not fulminate, or will do so but feebly, if it is not thoroughly washed before drying; warm water is directed, but I find that cold water answers very well.

‡ When the ammonia begins to be in excess, we perceive it by the pungent odor, which is immediately removed by a little more of the nitro-muriatic solution.

§ The old chemists used to dissolve gold by nitric acid and muriate of ammonia; the precipitate from this by an alkali was fulminating: the same, if thrown down from the nitric or sulphuric acid, and the fulminating gold is formed by digesting pure ammonia on oxide of gold free from acid.

|| Wrapped in thin paper with a projecting piece, and held by the small tongs, Vol. I, p. 500.

¶ Although it is much less liable to explode by friction than the fulminating powers of mercury and silver, it is improper ever to subject it to the friction of a glass stopper. M. Fasciau, holding in his hand a bottle half full of the fulminating gold, by turning the stopper, exploded the whole, and the fragments of glass destroyed his sight.—*Laugier*.

all at once, like the filters of fulminating mercury and silver, but in patches and spots.

(f.) *Acids and other liquid reagents do not decompose it unless heat is applied, at the same time, to the degree at which it explodes without them.*

(g.) *By very gradual heating, especially in contact with powdered chalk or any pulverulent substance, it may be decomposed* without explosion,† and it may be exploded in a strong vessel without bursting it.*

(h.) *It explodes in the solar focus, and by electricity, but not by a spark from flint and steel.*

(i.) *It is simply a compound of oxide of gold with ammonia.*

(j.) *The action, at the instant of explosion, consists in a combination of the oxygen of the oxide of gold with the hydrogen of the ammonia, to form water in the state of steam, and in the liberation of nitrogen gas and metallic gold; the nitrogen occupies 1000 times the volume of the fulminating powder.*

DECOMPOSITION OF MURIATE OR CHLORIDE OF GOLD BY VARIOUS SUBSTANCES.

(a.) *The solution of gold being evaporated to dryness, to expel any superfluous acid, using a gentle‡ heat so as not to decompose it, is removed from the fire when it is sufficiently evaporated to become solid in cooling; it is then redissolved in distilled water, and is in a fit condition for exhibiting the properties of dissolved gold.*

(b.) *The green§ sulphate of iron, becomes red, and throws down metallic gold in the form of a dark cloud, which, when washed and melted or rubbed, exhibits the proper color of gold; it sometimes is soiled by a little iron, which is removed by muriatic acid, and then is pure. This is a good test for gold; but silver is said to be precipitated by the same means.|| The action of the green sulphate of iron is explained by supposing the oxygen of the oxide of gold to be attracted by the iron, which passes to the state of peroxide; those who regard the solution of gold as a chloride, suppose water to be decomposed, to afford its oxygen to the iron, and its hydrogen to the*

* Berthollet decomposed it in a copper tube, and exploded it in copper vessels.

† Its application in covering porcelain was mentioned, Vol. I, p. 291, Note.

‡ Without a careful attention to the degree of heat, we are very apt to obtain a film of metallic gold upon the bottom of the evaporating vessel.

§ The green crystals obtained by filtering the solution of iron made in the usual process for hydrogen gas, by dissolving iron filings or turnings, in dilute sulphuric acid, if redissolved, precipitate gold with great delicacy, and so does even the acid sulphate of iron that remains in solution in the above named process.

|| This is however an immaterial fact, for silver would be instantly precipitated by the muriatic acid alone, before the application of the test for gold.

chlorine, while the gold falls; the latter explanation appears highly improbable.*

(c.) *Clean iron precipitates the metallic gold*; dilute the fluid with alcohol, instead of water; when the gold is precipitated on the iron, it may be made to adhere by means of a burnisher; this is the most economical mode of gilding iron.†

(d.) *Copper, zinc, bismuth, and mercury, precipitate the gold*; the former with remarkable energy; the acetate of copper also throws down metallic films.

(e.) *Silver, lead, and their acetates throw it down in the form of a purple oxide.*

(f.) *Tin readily precipitates gold*, giving origin to what has been called, from its discoverer,‡ *the precipitate of Cassius*.

(g.) *Dilute the solution of gold very largely with water, immerse a sheet of tin, or tin-foil, or some grain tin, or drop in muriate of tin, recently prepared without heat, (proto-muriate); even that prepared with heat, by dissolving tin in 2 parts nitric and 1 muriatic acid, mixed with an equal bulk of water, will precipitate the gold*; to this solution, largely diluted, half as much muriate of gold is added; the liquor becomes red, and the flocculent red precipitate is washed and dried.§

(h.) *This purple precipitate is the only thing known that gives to glass the fine red color, resembling ruby*; it is supposed to be produced by a mixture of the oxides of tin and gold, or as some think, by the oxide of tin and metallic gold, and the latter opinion seems now to be established; the color produced upon porcelain inclines more to purple, when the muriate of tin is in excess, and to red in the opposite case; a violet compound contained 60 oxide of tin, and 40 metallic gold, and one of a fine purple, 20½ oxide of tin, and 79½ gold.—Henry.

(i.) *Charcoal, well burnt, being immersed in a diluted solution of muriate of gold, placed in the sun's rays, the gold is precipitated, and without the sun's light, if boiled.*

(j.) *A stick of phosphorus immersed in muriate of gold, is in a few days covered with the metal.*

(k.) *Sulphurous acid mixed with muriate of gold reduces it to the metallic state; so does phosphuretted hydrogen and hydrogen.*

* Dr. Thomson is of the opinion that the gold is in the state of a muriate. See his memoir, Edin. Phil. Trans. 1827.

† Aikin's Dict.

‡ Dr. Cassius, 170 years ago.

§ Into a gallon of water, pour a drachm measure of the solution of muriate of tin, and add 20 or 30 drops of the muriate of gold to a gallon of this fluid; the precipitate will subside in the course of 3 or 4 days. The addition of potassa or its sulphate, hastens the precipitation.

(l.) The latter was ingeniously applied by Mrs. Fulhame to gild ribbons moistened with a solution of muriate of gold by means of a camel's hair pencil; the effects do not take place unless water is present; the ribbons may be held over the gas as it rises from the materials.

(m.) *Ether and volatile oils decompose muriate of gold*; highly rectified ether being shaken in a tube with muriate of gold, the latter is decomposed, and the oxide is dissolved by the ether. This solution was anciently called *Aurum potabile*. It has been used for gilding lancets and other delicate instruments.*

(n.) Gallic acid produces a dark precipitate in muriate of gold; it is decomposed by oxalic acid in the sun's rays, and the bin-oxalate (salt of sorrel) is still more efficient; carbonic acid is evolved, and in an hour, the gold is revived; cream of tartar produces the same effect, but more tardily; but tartaric acid does not produce it at all.

V. COMBUSTIBLES.

1. Sulphur.

(a.) *Sulphur does not combine directly with gold*; but if digested or fused with an alkaline sulphuret, a greenish solution may be obtained; an acid throws down the gold combined with sulphur, which is exhaled by the fire, and gold remains.

(b.) *Sulphuretted hydrogen, passed through a solution of muriate of gold, precipitates a sulphuret* composed of gold 80.39, + sulphur 19.61, which is very nearly in the proportion of one equivalent of gold 200, and 3 of sulphur 48.

(c.) The alkaline hydro-sulphurets precipitate gold from the solution in aqua regia, and form a yellow sulphuret with a variable proportion of sulphur.

The sulphuret of gold is soluble in hydro-sulphuret of potassa.

* It is very easy to shew the transfer of the gold to the ether; the latter should be highly rectified, and the fact is best exhibited by taking a long test tube and mingling the fluids by agitation; instantly after they are at rest, the ether will become yellow, and will float on the water which retains the acid of the solution; if standard gold has been used, it will be blue, on account of the copper. I have kept a saturated solution of this kind twenty years, in a broad vial; as the ether gradually wasted, it became covered with a film of metallic gold, which in time fell, unbroken, to the bottom, and was succeeded by several others which also fell in succession, until the solution was nearly all decomposed.

To prepare the ethereal solution neatly, the muriate of gold must be obtained solid and free from acid; it must then be dissolved in distilled water and the ether added; we have then the singular spectacle of the heaviest of all bodies, except one, suspended in the lightest of all fluids. Into this solution a bright steel blade may be plunged, and it will come out gilded sufficiently to be easily observed; but it requires repeated immersions and much care to obtain a good coating. The ethereal solution is sometimes applied by a pen or brush.

The phenomena of the ethereal solution of gold seem particularly inconsistent with the supposition that the common solution is a chloride, but as the gold appears to exist in the ether in the state of oxide, they are easily explained upon the supposition that it is a muriate. Oil of turpentine is nearly as active as ether in dissolving the gold, and is much cheaper and not so inconveniently volatile.

2. Phosphorus.

(a.) *Phosphorus combines with gold*, in either of the usual ways, viz. phosphoric glass and charcoal are heated with gold, or phosphorus is dropped on melted gold, or heated in a tube void of air, along with divided gold.

(b.) *Color whitish; brittle*; phosphorus burns off and leaves metallic gold.

(c.) *Phosphuretted hydrogen also precipitates gold* from its nitromuriatic solution, in the form of a phosphuret.

V. IODINE *combines with gold* by the action of its oxide upon hydriodic acid, or of the muriate of gold upon hydriodate of potassa. There is an abundant yellowish brown precipitate, insoluble in cold water and sparingly soluble in hot; at 260° Fahr. it is decomposed by heat, by nitric and sulphuric acids, and by liquid alkalies. Composition—iodine 34, gold 66. (H.)

VI. BROMINE *unites with gold*; its aqueous solution dissolves it; the yellow compound stains animal bodies violet; the solution of bromide of gold is red and it affords crystals of hydro-bromate of gold, water yielding its elements. One grain of the crystals perceptibly stains five thousand grains of water.

VII. ALLOYS.—Gold combines with many metals.*

1. MANGANESE;† *the metal, at a high heat, combines, $\frac{1}{4}$ to $\frac{1}{2}$, with gold*; color reddish gray; receives a steel polish; hard, slightly flattens under the hammer.

2. ARSENIC, on account of its volatility, *combines with gold reluctantly*; it is made to unite by being immersed in volatilized metallic arsenic, or by heating together gold, black flux and white oxide of arsenic; it is gray and brittle, with a granular fracture; the arsenic is not all separated by heat; plated gold, suspended in a hot atmosphere of arsenic, melts superficially; the alloy falls in drops and leaves a smooth surface of pure gold.

3. COBALT, 4 grs. to 1 oz. of gold; alloy paler than gold, slightly brittle; sp. gr. little changed; with 48 grs. cobalt to 6 oz. of gold, more brittle; fracture earthy.

4. ANTIMONY; with fine or standard gold, $\frac{1}{4}$ of a gr. to 1 oz., ($\frac{1}{15}$ of antimony) gives an alloy brittle, granular, dull and bulky, and destroys the ductility of gold.

5. ZINC, *in vapor, unites with gold*, and impairs or destroys its ductility; alloy brittle; $\frac{1}{4}$ fine brass forms a pale yellow granular

* Mr. Hatchett, Phil. Trans. 1803. The experiments were made on proportions from $\frac{1}{15}$ to $\frac{1}{4}$ of a grain, or $\frac{1}{15}$ of the whole mass. They were undertaken by order of the British government, in relation to their coinage.

† The manganese was mixed with olive oil, which was burned off several times; then placed in a crucible, lined with charcoal, and the gold was placed in the midst of the oxide.

compound; with 3 parts zinc and 1 gold, the alloy is still malleable, and equal parts form a metal that takes a high and permanent polish; it has been proposed as a material for the mirrors of telescopes.

6. **BISMUTH**, 38 grs. to 1 oz. of gold; a brittle, pale greenish yellow alloy; sp. gr. greater than the mean; gold is rendered brittle by bismuth; even by $\frac{1}{4}$ gr. to the oz. although unchanged in color and texture; the fumes of bismuth, even in open vessels, destroy its ductility.

7. **TIN** 38 grs. to 1 oz. of gold, gives an alloy yellowish gray and flexible in thin pieces; sp. gr. 17.307; either tin or bismuth $\frac{1}{4}$ gr. added to gold alloyed by copper, renders the gold very spongy and diminishes its specific gravity; but tin, if pure, is not so injurious to the ductility of gold as has been supposed, the effects attributed to it having probably arisen from bismuth, lead, antimony or zinc, mixed with it.

8. **LEAD**; *its fumes affect gold much as those of bismuth do*; 38 grs. to the oz. give an alloy resembling pale fine gold externally, but brittle as glass; internally brown, dull and porcellaneous; $\frac{1}{4}$ gr. to the oz. still renders the gold perfectly brittle; it is very brittle when the lead is only $\frac{1}{15}$ of the alloy.

9. **IRON**, *in all its forms*, of bar or cast iron; or steel, *will unite with gold*, in the proportion of 38 grs. to 1 oz. of gold, without diminishing its ductility; the alloy is pale and hard; sp. gr. 16.885, less than the mean; obeys the magnet and is said to be superior to steel for cutting instruments; it may probably be employed in the arts.

10. **COPPER**; 38 grs. (standard proportion,) to 1 oz. of gold, gives a deep reddish yellow alloy, harder than gold and very ductile; sp. gr. much less than the mean; equal parts form a very ductile alloy.

Sometimes copper, probably from its containing lead or antimony, *renders gold brittle* as glass, and $\frac{1}{15}$ is sufficient to produce this effect. *Gold coins usually contain about $\frac{1}{15}$ of copper*, which renders them harder; sometimes, as in British coin, the alloy is composed both of silver and copper,* and there is always a small quantity of silver in native gold.† In France, the gold coin is composed of 1 part of copper and 9 of gold.‡ Ornaments and utensils are

* Average sp. gr. of British gold coins 17.5, but it has varied in different reigns. 20 lbs. Troy produce 934½ sovereigns; 1 lb. was formerly coined into 44½ guineas; now it is made into 46½ sovereigns.—*Webster's Manual*.

† This is separated by the agency of nitric acid; cupellation with lead first takes away the copper; three times as much silver as gold is added and the nitric acid then easily removes the whole of the silver, although without the addition of more silver, it could not abstract the very minute quantity that existed in the gold.

‡ Black lead crucibles are used in forming this alloy, and wrought iron in making that of silver, for the French coinage.—*Thénard*.

made of this alloy; in France it contains, in different cases, 820, 840 and 750 parts of gold in 1000, the rest being copper. *In the United States the gold coins have $\frac{1}{10}$ alloy, which may be composed of any convenient proportions of copper and silver, provided the latter is not in excess.**

11. NICKEL; 38 grs. to 1 oz. gold, the alloy is like brass; sp. gr. less than the mean; with 8 grs. slightly brittle; with 4 still perfectly ductile, and among the metals formerly called semi-metals, nickel is the least injurious to the color and ductility of gold.

12. MERCURY *unites readily with gold*, by mere contact; gold, rubbed with mercury in the palm of the hand, is instantly amalgamated; a drop of mercury falling on a plate of gold is immediately flattened, and the gold is whitened.

Rub in a mortar, gold leaf with mercury and hot water, or heat divided gold with mercury in a flask or crucible, and a compound is formed. A bar of gold immersed in mercury, is in a few days penetrated and rendered brittle.

This amalgam may have any degree of consistence according to the proportions; with mercury, 6 or 8 parts and gold 1, it crystallizes in tetrahedral prisms, is very fusible, and exhales the mercury by a moderate heat, leaving the gold pure.

13. SILVER *unites with gold in all proportions.*

It dilutes the yellow color of gold, gives it hardness and elasticity, and the compound is more sonorous than either metal alone; ductility much the same; fusibility greater than that of gold; native gold is said to be always alloyed by a little silver: silver is not however always alloyed by gold, but the ingots of both metals, found in commerce, contain, reciprocally, each a little of the other, but the gold cannot be extracted with advantage unless it amounts to $\frac{3}{1000}$ parts. *Thénard.* Only silver and copper are proper for alloying gold, as all other metals alter the color and diminish the ductility; the latter property is affected by the following metals in the following order, beginning with those that affect it most. Bismuth, lead, antimony, arsenic, zinc, cobalt, manganese, nickel, tin, iron, platinum,† copper, silver.

* The eagle of ten dollars contains 270 grs. of standard gold, of which 247½ are fine gold and 22½ grs. alloy. The troy pound of standard gold contains 11 oz. fine gold and 1 oz. alloy; it is coined into 21½ eagles, of the value of 213½ dollars, or 9 oz. standard gold are coined into 16 eagles, of the value of 160 dollars. One pound of fine gold is, in this country, worth 15 lbs. of fine silver; in estimating the comparative value of coins, the alloy is disregarded and the fine metals are compared. "Thus 24½ grs. of fine gold, being one tenth of the fine gold in our eagle, are equivalent to our dollar, and multiplied by 15 produces 371½, the grains of fine silver in the dollar."—*Webster's Manual.*

† Mr. Hatchett's experiments having been made on platinum not absolutely pure, the order assigned this metal may not be exactly correct.

Green gold is obtained by melting 708 grs. of pure gold with 292 of pure silver.

Remark.—*The fineness of gold is expressed by the number of parts which it contains of gold; it is supposed to be divided into 24 parts called carats: if it contains 10 parts of alloy it is 14 carats fine, and 24 carats fine when it is absolutely pure.*

VIII.—NATURAL HISTORY.—*Gold is never mineralized, but it is frequently alloyed by silver and copper, and sometimes by palladium, tellurium and other metals. It is also mechanically dispersed, in small proportions, through various ores of some other metals, as iron pyrites, galena and blende, which are then denominated auriferous.*

*There is a rich region of gold in the United States, first observed in North Carolina, but extending south to Alabama and north to Virginia; the gold was at first found principally loose in sand and gravel; afterwards in veins, but most of it is now obtained from the powder of ferruginous and earthy masses in which it is dispersed, and from which, after they are raised by mining, and ground fine by machines, it is extracted by amalgamation. Loose masses of gold have been found of several pounds, even up to twenty eight, and of every size down to microscopic spangles and grains.**

IX. EXTRACTION.—*Much gold, in fragments and grains, is found loose in the sands and diluvial ruins of many countries, and is picked out or obtained by washing, or by amalgamation with 5 or 6 parts of mercury. The latter process is of great importance and the quick-silver may be saved by distillation or allowed to escape in vapor. Ores that contain gold are roasted and the reduced metal is cupelled with lead.*

X. ASSAY AND PURIFICATION.

1. *Copper is separated by cupellation with lead; if the proportion of copper is small, silver is first added; the lead and the copper are absorbed by the cupel, and the silver is then in a condition to be dissolved by the nitric acid.†*

2. *This is called parting.* It is singular that silver in very small quantity cannot be separated from gold by nitric acid, but it is easily removed if more silver be previously added by fusion: about 3 parts‡ to 1 are the usual proportions. The metal is laminated and corroded in a glass flask with 2 or 3 parts of nitric acid, sp. gr. 1.25, aided by a coal fire; action having ceased, the fluid is poured off, and more acid of rather greater strength is added and again heated. The gold

* See Am. Jour. Vols. 9, 12, 13, 16, 17, 18, for the facts and opinions respecting its geological relations. This gold is 23 carats fine.

† Our goldsmiths are accustomed to add silver to their gold; they melt them together, and then dissolve the silver out by nitric acid. The process of touching, by touch-needles and by touch-stones, affords a coarse way of judging of the proportion of gold. See Alkine's Dict. Art. assay.

‡ Hence called quartation because the gold forms but one fourth part: two parts of silver are sufficient, but more than three parts can be separated as easily as less.

is carefully washed and melted. The silver is recovered by processes already described under that metal.

3. *Gold is purified by sulphuret of antimony*; it is thrown in successive portions upon the alloy melted in a crucible, and the foreign metals, particularly iron, copper, lead, tin, and silver unite with the sulphur, and the gold with the metallic antimony; the latter is burned off by a stream of air directed upon the melted alloy, and by the addition of nitre, and thus the gold is left pure.

XI. GILDING.—Notwithstanding its costliness, *gold*, from its beauty and from its not being liable to tarnish, is *almost the only metal used to cover large surfaces*, especially on the outside of buildings. Gilding is performed in several ways.*

1. *By amalgamation*.—Pure gold, prepared by parting by aquafortis, is laminated and added in pieces to 8 or 10 parts of very pure quicksilver, heated almost to boiling, and about half the quicksilver is evaporated. This is applied warm upon silver, cleaned by boiling in weak muriatic acid, also warmed, and a clear charcoal fire evaporates the mercury; more amalgam is added if necessary, and the roughnesses are removed by a scratch brush;† the pale color is improved by smearing it while warm with gilders' wax,‡ which is burnt off once or twice,§ and the highest lustre is given by burnishing. Copper and brass are gilded in the same manner, only the adhesion of the amalgam is aided by a previous precipitation of mercury from its nitrate upon the copper cleaned by nitric acid. Brass or copper buttons|| may be gilded in this mode; they are burnished by the bloodstone. The above is called water gilding.

2. *By gold powder*.

(a.) *Prepared by grinding gold leaf* in a glass on earthen mortar, with honey or gum water, till it is minutely divided, and then the honey or gum is removed by water;

(b.) *By precipitating gold by copper* from its nitro-muriatic solution, digesting the powder in distilled vinegar, and washing and drying;

(c.) *By evaporating the mercury from the gold amalgam*, stirring it to prevent adhesion, and afterwards grinding it with water and drying it. These powders are applied by adhesive compositions.

Sometimes a linen rag is dipped in the solution of gold and burned, and the black powder is rubbed by a moistened cork upon the me-

* Alkms' Dict. Art. Gilding, which see for many particulars.

† A tuft of fine brass wire.

‡ Composed of bees wax, red ochre, alum, and green vitriol; when the wax is burnt off, the piece is quenched in urine.

§ Sometimes a mixture of equal parts of nitre, sal-ammoniac, verdigris and green vitriol; or of nitre, common salt and alum, are employed for the same purpose.

|| 5 grs. of gold will gild 144 buttons of an inch in diameter, on both sides.

tallic surface till the gold appears, when it is burnished ; this was formerly applied chiefly to silver, and is now disused.

3. *By gold leaf.*

(a.) *Wood is gilded* by first priming it several times with boiled linseed oil and white lead, and then covering it with gold size,* upon which the *gold leaf* readily adheres ; it cannot be burnished, but can be cleaned with water and a soft brush ; it is used principally on out door work.

(b.) *Burnished gilding or gilding in distemper*, as it is called, is performed by covering the surface with a strong size or glue, and then with 8 or 10 coatings more of the size mixed with *plaster of Paris* or chalk, and lastly, a layer of size mixed with bole ; before this last coat is dry, the *gold leaf* is applied, and by a slight pressure of a cotton ball, it adheres, and before it is quite dry, those parts that are to be brilliant are burnished with an agate or a dog's tooth. This gilding is applied chiefly to picture frames, looking glass frames and other in-door work. I have observed the gilders here to wet the coating of plaster of Paris with spirit ; the evaporation appears to generate electrical attraction ;† for, the gold leaf, when suspended and brought near, instantly flies to the surface, clings to it and covers every irregularity completely.

(c.) *Gold leaf is applied to paper, vellum, signs of shops, &c.* and to books by various adhesive substances, such as size alone, or mixed with white lead, and for book covers, sugar candy and bole, rosin and mastic, aided sometimes by a heated iron.

(d.) *Drinking glasses* and other utensils are gilded by applying an *adhesive varnish* of drying oil and the resin, animé or amber, diluted with oil of turpentine ; the vessel is warmed, and the *gold leaf* applied while the varnish is soft ; it is then burnished before the varnish is hard.

(e.) *Sometimes the gold is applied*, both to glass and porcelain, in the state of *gold powder* mixed with gum water and borax ; a slow heat burns off the gum and vitrifies the borax ; the gold is thus burnt in, and is then burnished.

(f.) *Copper, iron and steel, are covered by gold leaf by adhesion and pressure* ; the burnished metallic surface is heated to the point of melting lead, or if it is iron, till it is blue ; a double layer of gold leaf is applied and carefully burnished by the bloodstone, and other layers are applied to make a solid gilding ; this mode is effectual but tedious.

(g.) *Silver and copper wire are gilded* in this manner, by applying *sheets of gold to a rod of the metal* ; then it is drawn through the plate,

* Made of calcined red ochre, ground with old and thick drying oil, and diluted with oil of turpentine to make it pliable ; it will dry in 12 hours.

† Agreeably to well ascertained facts.

and the union is perfect, although the wire is extended to extreme fineness. To form gold thread, the wire is flattened by polished steel cylinders, and wound by a machine around the thread; its continuity is unbroken, although it is said that its thickness is but the $\frac{1}{100000}$ of an inch.*

Gilding by ether has been already mentioned.

The ancient Romans were remarkable for a prodigal use of gilding, and the modern French have followed their example, both on public and private buildings.

XII. POLARITY.—*Electro-positive*, and like other metals, it goes to the negative pole.

XIII. MISCELLANEOUS.—The uses of gold are sufficiently obvious from the common experience of mankind, as well as from the preceding details; the most important are for a coin and for ornamental purposes.

Gold has been used in medicine; and for the discussion of the controverted question of its utility in certain cases, as a substitute for mercury, we refer to the medical authorities. It has been employed in the form of aurum potabile, (etherial solution;) divided gold; oxide; ammoniacal oxide and of the precipitate by tin and its muriate; all these have been described. It remains only to add, that a soda-muriate has been used in medicine, formed by adding an equal quantity of common salt to the evaporated muriate, (chloride,) dissolving them in distilled water, and evaporating them again to dryness.

Remark.—Humboldt estimates the whole quantity of gold produced annually by South America and New Spain, to be nearly 11,000,000 of dollars. Europe furnishes about $\frac{1}{10}$ as much, and most of this comes from Hungary.—*Thénard*.

SEC. XXXVI.—PLATINUM.†

I. HISTORY AND NAME.—First mentioned by Don Ulloa,§ in 1748, in an account of a voyage to Peru, made in 1735. Mr. Wood, assay master of Jamaica, first discovered it and brought it to Europe, but his observations were not published until 1749–50.‡ Many distinguished chemists examined it in the latter half of the last and beginning of the present century.

* Bigelow, Technol. p. 394.

† The word platina, in Spanish, is a diminutive of plata, and means little silver, upon the idea that it is related to that metal.

‡ See Philos. Trans. In that year, specimens were presented to the Royal Society by Dr. Brownrigg; they came from Carthage; toys and trinkets had been dispersed through the Spanish West Indies, made from an alloy of platinum, probably with silver.

§ He accompanied the French academicians who went to Peru to determine the figure of the earth.

II. PROPERTIES.

(a.) *Color white; intermediate between that of silver and tin, or tin and iron.*

(b.) *When pure, it is soft, is easily cut by scissors or scratched by the nail, but if alloyed by any metal, especially iridium or osmium, it is very hard.*

(c.) *The heaviest metal, and of course the heaviest substance known; sp. gr. at the maximum, formerly stated at 23 or 24, now at 21.5, as it is found in fine platinum wire.**

(d.) *Has considerable elasticity; sufficient, as has been said, for making the pendulum spring of watches; receives a high polish.*

(e.) *Very malleable, ductile and laminable; wire is easily drawn from it of $\frac{3}{8}$ inch and even $\frac{1}{8}$ of an inch diameter. Dr. Wollaston has drawn it to the fineness of $\frac{1}{8}$ inch, and by great care, even to $\frac{1}{16}$ inch.†—Murray.*

(f.) *It may be beaten and rolled into leaves as thin as tin foil; they are now common in laboratories, and are of great utility in wrapping up substances that are to be exposed to heat.*

(g.) *Tenacity, a little inferior to that of iron; if the latter breaks with 600 pounds, platinum requires 590, and gold 500.—Wollaston.*

(h.) *Less dilatable by heat than most metals, and also a less perfect conductor; it is $\frac{1}{18}$ as good as copper, and $\frac{1}{13}$ as good as silver.‡*

(i.) *Capable of being welded;§ divide the pieces in a slanting direction, by a sharp tool; the surfaces being heated to full redness will unite firmly by the blows of the hammer; if the surfaces are burnished they do not unite.*

(j.) *Of very difficult fusion; does not melt, or suffer any change in porcelain or glass house furnaces, or, without addition, in any furnace. Platinum crucibles come out of the furnaces unaltered, even in symmetry.||*

* A button that had been melted, had the sp. gr. 21.16; the mean gravity, after forging, is 21.25, and that of some rods after drawing, 21.4.—Wollaston.

† Dr. Wollaston succeeded by fixing a large platinum wire in the middle of a hollow cylindrical mould; silver was then cast around it, and after being drawn sufficiently through the wire plate, the silver was dissolved by nitric acid, which left the platinum untouched. A similar arrangement was adopted by M. Becquerel, Ann. de Chim. et de Phys. Vol. XXII, p. 113; he used a mould of earth, and he drew steel wires of extreme fineness in the same way, only the silver was removed by the action of mercury, but several precautions are necessary for success.

‡ Both on account of its infusibility and its slow conducting power, it is much used to make forceps and spoons for holding substances used in blowpipe experiments.

§ It must not be held by the iron tongs while it is heating, for it combines with the iron; only these two metals have the welding property; except that pieces of sodium when first cut, unite by pressure; I attempted to have platinum welded by a good black-smith, but he did not succeed; a thin film of iron from his tongs soon covered the metal, and the surfaces would not unite.

|| At a full white heat, utensils of this metal are so soft as to be impressed by hard substances, and the injury they would thus suffer, can be avoided only by enclosing them in smooth clay vessels.—A. A. H.

(k.) *Fused by the most powerful lenses* and by concave mirrors—*by oxygen gas, directed upon burning charcoal; *by the compound blowpipe* it is melted with the greatest facility; a platinum wire held in its focus melts as readily as wax in a candle; it scintillates, falls in ignited drops, and some of it is even volatilized.

It was melted, when imbedded in charcoal, and heated in a wind furnace;† in contact with charcoal, *it fuses in small quantities with fluxes*, as borax and glass; *delicate points* may be melted *by the common blowpipe*.

III. RELATION TO OXYGEN.

(a.) *Not oxidized by heat and air*, and suffers no change from them even by unlimited exposure; the crude grains of platinum become indeed dull, but the change is owing to iron or other impurities.

(b.) Wires of platinum are apparently oxidized by powerful galvanic and electric discharges.

(c.) Effectually oxidized by nitro-muriatic acid, and in some measure by hot nitre.‡

(d.) OXIDES.—It is supposed that there are two oxides of platinum, both of which are reducible by heat alone—the oxygen being expelled, and the metal remaining; therefore, and on account of its other properties, it is a noble metal.

(e.) As the only effectual method of obtaining the oxides of platinum is by the action of nitric and muriatic acid, we must, as in the case of gold, anticipate in mentioning the muriates or chlorides now.

(f.) Protoxide.—Obtained by the action of a solution of potassa on the proto-chloride, or proto-muriate, of platinum; it is in the state of a black hydrate, and consists§ of 96, or 1 equiv. of the metal, and of 8, or 1 equiv. of oxygen = 104; *this result is obtained by weighing the precipitate, expelling the oxygen by ignition, and then weighing the metallic residuum.

(g.) Deutoxide or peroxide.—Obtained by decomposing the nitrate with a gentle heat, or by precipitating the sulphate by potassa. Laugier. Or, by evaporating the muriate almost to dryness—diluting the residue with water, and decomposing it by nearly an equal weight of caustic soda; the oxide is black; in the state of hydrate it is yellow like rust; its composition is 1 equiv. of platinum, 96 + 2 equiv. of oxygen, 16 = 112.||

* A globule of 29 grains boiled violently in the focus of a lens three feet in diameter.—H. and Ann. de Chim. Vol. LXIX, p. 33.

† Man. Mem. Vol. III, p. 467.

‡ Phil. Trans. 1797.—Tennant.

§ Berzelius, Ann. de Chim. et de Phys. Vol. XVIII, p. 147.

|| A tritoxide of platinum has been described by Mr. E. Davy, (Phil. Trans. 1820); it was obtained by boiling together strong nitric acid and fulminating platinum, drying the product by a heat just below redness, and then washing, first with water, and afterwards with a little potassa; its composition appears to be one equiv. of pla-

IV. RELATION TO ACIDS.

(a.) *Platinum is acted on by no acid, except the nitro-muriatic, which is therefore the appropriate solvent; the best proportions are 3 muriatic to 1 nitric—with the application of a moderate heat; the phenomena are extremely similar to those which attend the solution of gold, and there is a great resemblance between the physical characters of the two metals.*

(b.) *The best method is to pour, in a glass retort, all the muriatic acid on the laminated metal, or on the grains if the native metal is used; then add $\frac{1}{4}$ of the nitric acid; apply a gentle heat; when the action ceases, add more acid, and so on till the whole is used; then distil over the superfluous acid into the receiver; it will dissolve more platinum, if more muriatic acid is added.*

(c.) 16 oz. muriatic acid + 4 nitric, will, by good management, dissolve 3 oz. $2\frac{1}{4}$ dr. of platinum.*

(d.) *Dr. Wollaston* (who had more experience with platinum than any other man) *recommends single aqua fortis*, sp. gr. 1.19 to 1.20, in such proportion that if it would dissolve 40 of marble, the muriatic acid should dissolve 150, and to this mixture 100 of crude platinum would be equivalent; the acids should be allowed to digest three or four days with a heat gradually raised.†

(e.) *State of the solution.*—The remarks that were made under a similar head in connexion with gold, are probably applicable here. It is not exactly agreed whether the solution is a chloride or a muriate; although the latter appears the most probable, the one supposition or the other may be admitted, as the phenomena may seem to require.

MURIATE OF PLATINUM.

We will describe the solutions as they ordinarily appear, and endeavor afterwards to distinguish their various conditions.

(a.) *The color of the solution, made from the native grains, is deep reddish or orange brown, but the brownish color is owing to iridium.*

(b.) *The color of the pure muriate of platinum is beautiful orange yellow, much resembling that of the muriate of gold, but rather more intense.*

(c.) *Taste acrid; crystals can be obtained by evaporation.*

tinum, $96 + 1\frac{1}{2}$ of oxygen $12 = 108$, which places it intermediate between the two other oxides. There is still some obscurity resting upon the oxides of platinum, and perhaps upon the equivalent of the metal. The color of this oxide is gray.

* Aikins, Proust.

† A fine pulverulent ore of iridium will subside, but of this mention will be again made in the proper place. See Phil. Trans. 1829, and Phil. Mag. and Ann. Vol. VI. p. 1.

(d.) *Decomposed by heat*; all volatile principles are expelled, and metallic platinum is obtained.

ACTION OF CHLORINE.—CHLORIDES.

(a.) *Platinum, heated in chlorine gas, is slowly acted on, and forms a brown or olive-colored chloride.**

(b.) It is dissolved also by the aqueous solution of chlorine.

(c.) *Perchloride, or muriate of deutoxide.*

By evaporating the solution to dryness by a gentle heat, the superfluous acid is expelled, and the solid chloride is obtained; "it is deliquescent, and is soluble in water, alcohol and ether;" light decomposes the latter solution, and deposits metallic platinum.

(d.) *Proto-chloride.*

If the per-chloride is heated to the point of melting lead, it gives up a portion of chlorine, and becomes proto-chloride. If unmixed with per-chloride, it is insoluble in water, which removes the per-chloride when they are mixed. It is supposed that the proto-chloride is composed of one equiv. of platinum, 96+2 of chlorine 72, and that the proto-chloride has half as much chlorine; but this point is not quite settled.†

TRIPLE COMPOUNDS.

(a.) *The solution of muriate of platinum, (per-chloride,) is decomposed by muriate of ammonia; this is a characteristic property; the precipitate, if pure, is of an orange color, and it is a compound of muriate of ammonia and chloride of platinum.*

(b.) *It is decomposed by a red heat, and platinum remains in the spongy form;‡ in this state it is very effectual in kindling a mixture of oxygen and hydrogen gases;§ this may be redissolved in nitro-muriatic acid, again precipitated as above, and again ignited and redissolved, and the solution will be free from the foreign metals.*

* The question is I believe unsettled whether this chloride, by solution becomes a muriate; if the general view of chlorides and muriates, at present entertained, is correct, it is not easy to assign a reason why this should not be the fact, or why the solution of the metal, effected by the nitro-muriatic acid, is not a true muriate. I give in the text the usual view of the chlorides of platinum, without however feeling satisfied that they are not muriates, at least when in solution.

† Ann. de Ch. et de Ph. Vol. 40, p. 110. A third chloride was named by Mr. E. Davy; and Berzelius, favors the existence of a sesqui-chloride.

‡ Vol. I, p. 223. It is in this state fit for solution, &c.

§ The late Prof. Dana, discovered that the vapor of ether or alcohol falling upon warm platinum sponge was ignited, as hydrogen gas is. Am. Jour. Vol. VIII, p. 198.

It is said that moistening the orange precipitate of platinum with strong ammonia, and then igniting it, gives a spongy platinum of great sensibility in producing ignition. Webster, quoting Hensmann's Repert. de Chim.

(c.) *The orange precipitate is soluble in water*, in the proportion of 1. oz to 8 or 9 pounds, and gives, by evaporation, small octohedral crystals.

(d.) *Composition*—1 equiv. of platinum 96, + 2 equiv. of chlorine 72, + 1 equiv. of muriate of ammonia* 54, = 222.

(e.) This triple salt *becomes a mere muriate or chloride of platinum* by the simple action of *nitro-muriatic acid* or chlorine; it is decomposed, in part, also by fixed alkalies and lime water.

(f.) *Potassa† and soda, both the pure alkalies and their salts, also form triple compounds with muriate of platinum*; they are yellow, exhale chlorine by ignition, and leave metallic platinum mixed with a chloride of the alkali.‡

(g.) One part of platinum with two of common salt, and some nitric acid being placed in a retort, distil over $\frac{1}{3}$; the remaining liquor gives fine prismatic crystals, 4 or 5 inches long, reddish brown, amber colored or coquelicot;§ a similar result is obtained by mingling a solution of common salt with muriate of platinum.

(h.) *These salts are compounds of the muriate or chloride of platinum, with the muriate or chloride of potassa or soda.*

(i.) The soda compound, considered as a chloride, is composed of 1 equiv. bi-chloride of platinum 168, + 1 equiv. chloride of sodium 60, + 8 equiv. of water 72, = 200, and the potassa compound is similar, omitting the water and substituting 76 for the chloride of potassium.

(j.) *Baryta, strontia, and lime, with muriate of platinum, present the same phenomena* as the alkalies.

(k.) Muriate of platinum is not decomposed by green sulphate of iron, nor by prussiate (ferro-prussiate) of potassa.

(l.) Tincture of galls gives a dark green color, becoming paler by standing.

(m.) Sulphuretted hydrogen gives a brown precipitate.

(n.) *Ether dissolves the muriate or chloride*, and this solution may be applied in the same manner as that of gold.

(o.) *Muriate of tin, is a most delicate test of platinum*; a solution nearly as pale as water, assumes a bright red color by a single drop of the solution of the recent muriate.

* Other ammonia muriates of platinum are described, Eng. Quar. Jour. of Science, May, 1829, p. 193.

† Potassa throws down also a portion of a reddish matter which forms octohedral crystals, a compound of iridium; if we continue to add the alkali, the yellow potassa muriate appears.

‡ The muriate of platinum is used to separate potassa from soda, or to indicate the presence of the former; the mixture of the double chlorides being digested in alcohol, the soda chloride only dissolves.—A. A. H.

§ Nich. Jour. Vol. IX, p. 87.—Henry.

(p.) *I have found hydriodic acid to be even a more delicate test of platinum than muriate of tin*, (p. 78 of this volume, and note;*) it produces, even in a very dilute solution, a red color which soon becomes deep red, and a metallic pellicle soon covers the fluid, and is very distinct after the repose of a night.

(q.) *Alkalies and nitre, at ignition, corrode platinum* very sensibly; hence platinum vessels cannot be used with caustic alkalies.

V. COMBUSTIBLES.

1. *Phosphorus easily combines with platinum* in any of the modes so often mentioned, or by passing phosphuretted hydrogen gas into the solution of the metal; a vivid ignition happens when the phosphorus and platinum combine in a tube, although exhausted of air.

It is a brittle, bluish gray powder, hard, infusible and decomposable by heat. It appears to combine in two proportions, producing a proto- and bi-phosphuret.

2. *Sulphur readily unites with platinum.*

(a.) *By heating the metal and sulphur together*.—Mr. Faraday† recommends to volatilize the sulphur through platinum ignited in a tube.

(b.) *By heating the orange precipitate of platinum and ammonia*, 10 parts, with sulphur 20.‡

(c.) *By passing sulphuretted hydrogen gas through the solution of the muriate*; this last, Vanquelin considered as a compound of sulphuretted hydrogen and oxide of platinum, but Dr. Henry thinks it is rather a bi-sulphuret; it is black.

The sulphuret, formed by the processes (a. and b.) is also black, infusible and contains 16 per cent. of sulphur.

Sulphate of platinum.

(a.) *Formed by the action of nitric acid upon the sulphuret or hydro-sulphuret.*

(b.) It is soluble in water,§ alcohol|| and ether; it crystallizes with difficulty, and is decomposed by a low red heat; its volatile principles are expelled, and platinum remains.

(c.) *Strong aqueous solution of the sulphate and alcohol*,¶ equal volumes, being agitated and allowed subsequent repose, or boiled together, will deposit a black powder which is edulcorated, till it is no longer acid, and it is then dried at about 250°.

* Also Am. Jour. Vol. VI, p. 376.

† Chem. Man. p. 311.

‡ Ann. de Chim. et de Phys. Vol. V, p. 262.

§ This solution is the best test for gelatine, which it precipitates entirely, or if any remains suspended, it falls on being boiled.

|| The sulphates of other bases, are generally insoluble in alcohol.

¶ The strength of the alcohol is not very material, and ether may be substituted for it.

(d.) It is insoluble and tasteless; *explodes when heated* on a slip of platinum or on paper, and the metal is reduced.

(e.) *In ammoniacal gas, it becomes ignited and scintillates*; it is also ignited by placing a particle of it on any porous body, as paper, sponge, cork, or asbestos, imbued with alcohol or whiskey, so that it can be used for kindling a match,* as it remains ignited till the spirit is consumed; the alcohol is decomposed, and acetic acid is formed.

(f.) Composition, platinum $96\frac{1}{2}$, per ct. with nitrous acid and a little oxygen and carbon.†

3. *Fulminating platinum.*‡

(a.) *Formed by decomposing sulphate of platinum by ammonia in excess*; the precipitate is a triple compound of sulphuric acid, oxide of platinum and ammonia; the washed precipitate is boiled almost to dryness, with solution of potassa, which takes the sulphuric acid and leaves the ammonia in combination with the oxide of platinum, and some ammonia in excess escapes; the precipitate is then well washed and dried gradually, during several days, at 212° .

(b.) *Brown*, of various shades, § 1 gr. heated to 400° or 420° F. on a slip of copper, *explodes with a flash of light and louder than a pistol*, and indents the copper; it does not explode by percussion, but decrepitates feebly, by friction, in a warm mortar; it explodes on heated paper, and $\frac{1}{4}$ of a grain tears it; when it is exploded between two slips of metal, the lowest|| is most impressed. By careful drying and gradual heating, its explosive power is much increased; it does not explode by the electric or galvanic spark; neither does fulminating gold.

(c.) As it is a compound of oxide of platinum, ammonia and water, the theory of its explosion is similar to that of fulminating gold. Mr. E. Davy states its composition thus,

oxide of platinum	82.5	{ platinum,	73.75
		{ oxygen,	8.75
water,	17.5		
	100		

VI. ALLOYS.

The useful alloys of platinum are not numerous, although it unites with most of the metals.

1. *SILVER forms a tolerably fusible white alloy*, malleable and brilliant when polished, but it scales and blackens by working; from fu-

* Mr. Davy made a tinder box upon this principle.

† The carbon was supposed by Mr. Davy, to be accidental.—Phil. Trans. 1820.

‡ E. Davy, Phil. Trans. 1817.

§ The color does not appear to affect its properties, unless the drying is pushed so far as partially to decompose it.

|| Probably because the greater heat there, both soften the metal and produces a more perfect action of the detonating powder.—J. T. I have no doubt that this reason is just, having observed the same fact, with other explosive powders.—B. S.

sion it crystallizes roughly on the exterior so as to resemble a coarse file.

2. *GOLD, by a forge heat, combines with platinum*, and the alloys in all proportions are more fusible than platinum; in the proportion of 38 grs. to 1 oz. it forms a yellowish white ductile hard alloy; it is so elastic after hammering, that it has been proposed to use it for watch springs.*

A little platinum debases the color of gold; † with $\frac{2}{3}$ gold, the color is that of platinum, and with 11 of gold to 1 of platinum, the alloy resembles tarnished silver, and is very ductile and elastic.

3. *MERCURY, by trituration with spongy platinum*, or less easily with the orange ammoniacal precipitate *forms an amalgam*, ‡ at first soft, but which soon becomes considerably firm, and has been much used in obtaining malleable platinum. A coating of platinum can be given to copper and other metals by applying to them an amalgam of spongy platinum and 5 parts of mercury; the latter metal is then volatilized by heat.

4. *LEAD combines with platinum with energy.*

Two equal pieces of the foil of these metals being rolled together and heated red hot at the edge by the blow pipe, unite so rapidly as to evolve much light and heat, and to scatter the melted portions around; tin, zinc or antimony rolled in the platinum foil, and heated in the same manner, gives a similar result.§

5. *IRON and COPPER unite readily with platinum.*

Artificial gold, as it has been called, is formed of copper 7 parts, platinum 16, and 1 of zinc, all pure; being mixed, they are fused in a crucible, under charcoal powder.|| This alloy resembles gold very closely in color, ductility and specific gravity.

6. *STEEL unites with platinum in all proportions*, ¶ and especially in the proportion of from 1 to 3 per cent of platinum, forms a tough and tenacious alloy,** well adapted for cutting instruments; with equal weights the alloy is hard and brilliant, has the sp. gr. 9.862,

* Phil. Trans. 1803, p. 83.

† Which effectually prevents its being used as a counterfeit of gold in coinage, as was formerly feared; it would be detected even in thousandth parts by the color of the button produced in cupellation.

‡ To prevent the entrance of air between the mercury and the glass in barometers, Mr. Daniel fixes a ring of platinum at the lower end of the tube, and this becoming to a degree silvered by the mercury, causes such a close adhesion that nothing can pass.

§ Ann. Phil. XIV. 230.

|| Revue Encyc. XXVII. 900.

¶ Faraday, Phil. Trans.

** Dilute sulphuric acid dissolves most of the iron, and leaves a sediment containing the platinum, with a little hydrogen, carbon and iron; the two former are removed by heating, and the latter by muriatic acid, so that the platinum remains.

and is fit for mirrors : wires of steel and platinum, when welded and polished, exhibit a beautiful, surface, especially if acted on by dilute acid ; for many purposes of science and art, platinum may be joined very usefully to iron or steel.*

7. *ARSENIC unites easily with platinum*, forming a fusible alloy. The alloy composed of 20 parts of arsenic and 2 of platinum is grayish white, brittle and fusible a little above a red heat. Jeannetty, a silver-smith at Paris, for a long time, employed arsenic to render platinum fusible, and by expelling it by heat, he gradually made the metal malleable.†

VII. *POLARITY*.—Like the other metals, platinum is electro-positive, and is attracted to the negative pole.

MODES OF WORKING PLATINUM,
(so as to obtain it in malleable masses.)

This subject has very much occupied the attention of chemists, and several methods have been devised, of which only a cursory notice is necessary, as Dr. Wollaston has given perfection to the process.

1. *By amalgamation*.—The amalgam already mentioned is rammed into a wooden tube, which is heated in a muffle till it is consumed and most of the mercury volatilized: the bar of platinum that is left, will bear to be carefully moved, and being cautiously heated, until the remaining mercury is expelled, it is forged at a very high heat.

2. *By arsenic*.‡—The application of this alloy to this purpose has been already mentioned. The arsenic is easily volatilized, especially with the aid of charcoal. Repeated fusion of the native platinum grains with an equal weight of oxide of arsenic, and pearlashes about $\frac{1}{4}$ part, gave a brittle mass saturated with arsenic. This was alternately heated in a muffle and plunged into oil, and the porous mass, after being digested in nitrous acid, and washed with water, was again heated in a crucible, compacted by a pestle, and at last forged in a smith's fire, and worked on the anvil. This method is no longer used.

3. *By heat and pressure*.§

(a.) The orange precipitate, by muriate of ammonia, is heated to whiteness, in a crucible placed in an air furnace, and a conical stopper is let down upon it, and pressure applied to compact the pasty mass, which is afterwards forged into bars.

(b.) The orange precipitate, nearly decomposed by heat into spongy platinum, is placed in successive portions, in an iron mould, $2\frac{1}{2}$ inches long by $1\frac{1}{2}$ wide, and is there compacted by blows struck upon

* Prof. Brande.

† He made in this manner a watch chain for the king of France.

‡ Ann. de Chim. XV. p. 29, and Aikin's Dict.

§ Tillock's Phil. Mag. Vol. VI, p. 3.

a wooden pestle, fitted to the mould, and the pressure is finished by an iron plug, driven by a screw press, till the air is all expelled. The mass thus formed is heated white hot, and carefully forged, and then cleaned with borax, and afterwards with dilute muriatic acid.*

(c.) *Dr. Wollaston's process.*—The nitro-muriatic solution is obtained by digesting the ore of platinum, with the acid for three or four days, with a heat gradually raised; at least 20 per cent. of the metal in excess being used beyond the acids, which are, the muriatic about 3 parts, diluted with an equal volume of water, and single aqua fortis,† sp. gr. 1.19, to 1.20, about 1 part, which will dissolve 100 grs. of crude platinum.

After subsidence of some iridium, the clear solution is precipitated by 41 parts of sal ammoniac, dissolved in 5 of water; the precipitate 165 parts, yields 66 of pure platinum.‡

The yellow precipitate is thoroughly washed and pressed, and then very cautiously heated in a plumbago crucible, with no more heat than will just expel the volatile matters, without producing much cohesion in the metallic particles.

The remaining operations, (omitting details, for which see Dr. Wollaston's paper,)§ consist in rubbing the grey powder between the hands, so that it will pass through a lawn sieve; the coarser parts are ground by a pestle and bowl of wood,|| and all is diffused in water, and allowed to subside as a metallic mud of platinum. That there may be no cavities, this is placed in a brass barrel, having a steel stopper, and subjected to strong pressure, by a machine; the compacted mass being removed from the mould, is ignited on a coal fire, to drive off volatile matters, and is then placed in a strong wind furnace, on an earthen stand, strewed with siliceous sand, and covered by a pot that does not touch the metal; it now receives a white heat, and to avoid breaking it, is forged with much manual dexterity; the ingots are then placed upon a platinum tray, under an inverted pot, and heated in a wind furnace; they are cleaned by being heated with a flux composed of equal measures of borax and pearl ashes,¶ which is itself removed by dilute sulphuric acid.

* Aikin's Dict.

† The proportions are indicated by the marble they will dissolve. 150 grs. for the muriatic, and 40 for the nitric acid, corresponding very nearly to 1 nitric and 3 muriatic acid.

‡ About 11 percent of platinum being still contained in the solution, is precipitated with the other metals, by clean iron bars, and again digested in nitro-muriatic acid; before the addition of the muriate of ammonia, 1 measure of muriatic acid is added to 32 of the solution, to prevent the precipitation of lead or palladium.

§ Phil. Trans. 1829, and Phil. Mag. and Ann. Vol. VI. p. 1.

|| Not of metal, which would polish them and prevent their uniting by forging.

¶ An excellent flux to clean platinum vessels; in the analysis of minerals, two parts of crystalline carbonate of soda may be substituted for the pearl ashes; this acts powerfully upon zircon and other minerals that yield reluctantly to other fluxes; nitre may be added if oxidation is desired.

The ingot may now be flattened into leaf, wire-drawn, or wrought in any other way.

VIII. NATURAL HISTORY.

(a.) *Usually seen in irregular flattened metallic grains or spangles*, which are far from being pure; they are mixed or combined with several metals, as sulphurets of copper, iron and lead, titaniferous iron, chromate of iron, gold, silver and mercury; the metals palladium, iridium, rhodium; an alloy of palladium rhodium and iron; an alloy of iridium and osmium, also in grains;* sp. gr. of the ore, between 15.60 and 18.94.

(b.) *The pieces commonly weigh but a few grains, and rarely exceed a line in diameter*; but a specimen presented by Humboldt to the king of Prussia, was of the size of a pigeon's egg, and weighed 1088.8 grs.; another at Madrid, two inches four lines in diameter, weighs 1 lb. 9 oz. 1 dr. or 11.640 grs.; a piece from the Uralian mountains, now at Petersburg, weighs 9½ lbs. avoird., almost seven times as much as the largest before known; it contains an alloy of iridium and osmium.

(c.) *Platinum has usually been found in sandy deposits, along with gold*, and most of it formerly came from Choco, in New Grenada; it has been found also at Matto-Grosso, in Brazil,† and in St. Domingo, in the bed of the river Yaki, at the foot of the mountains of Sibao.

Vauquelin found it, in the proportion of one tenth, in the gray silver ores from Guadalcanal, in Spain.

In Siberia, it is found in the auriferous sands of Kuschwa, in the Uralian mountains, 25 wersts from Catherinburgh; the richest beds of platiniferous sand are at Talul, 2½ to 5 feet thick, and yield from 1 to 3 lbs. of metal for about 3700 lbs. of sand; they are also rich in gold; 1460 lbs. of gold were obtained from 225,000 of sand, and masses of 2 to 3, and even 18 to 20 lbs. were found.

In the middle and northern parts of the Uralian mountains, the platinum is abundant only on the western or European slope, while the rich gold washings are on the Asiatic side.

The metals found in the South American ore of platinum are found also in that of Siberia; native palladium, an alloy of iridium and osmium, &c.

Boussingault† has recently discovered platinum in a native vein, which is in a syenite, along with oxide of iron and gold; the grains have the same appearance as when it is found loose in the sands; it

* Mixed with the platinum ore, are found sand, rubies, &c.

† The Peruvian ore of platinum never contains gold, but the Brazilian has a little adhering to it, and the gold contains one fifth of silver.—Phil. Trans. 1809.

‡ Ann. de Chim. et de Phys. Vol. XXXII, p. 211. See also Phil. Mag. and Ann. Vol. III, p. 72, 282; Vol. IV, p. 308, 458; Vol. VII, p. 59.

is near *Santa Rosa*, in the Province of *Antioquia*, about 3500 feet above the sea level.

It is said that the Russians are coining large quantities of platinum into money; it would be excellent for coin.

IX. MISCELLANEOUS FACTS.

(a.) *Platinum and gold have many analogies*; in specific gravity; in solubility in the same agents; in their reluctance to combine with oxygen, chlorine and sulphur,* and in the formation of triple compounds with acid, alkaline and earthy substances; the oxides of both yield fulminating compounds with ammonia, and in this respect they resemble silver. Bouissingault has found that *platinum melts in a blast furnace* if placed in a *crucible brasqué*, viz. lined with charcoal and clay, but he supposes that the metal is then alloyed by the bases of the earths.

(b.) *Platinum is a metal of great utility*, and it is to be hoped from the increasing quantity discovered, that it may soon come into extensive use in the arts.

It is even now used to form boilers to concentrate sulphuric acid. Mr. Parkes had one constructed which cost 300 guineas.

Its use in chemistry is invaluable, for crucibles, foil, wire, tubes, capsules, retorts, for blowpipe jets, forceps and spoons, in the form of sponge for igniting hydrogen, &c.

It is used for the touch holes and pans of fire arms, and for the bottoms of evaporating basins,† &c.

Being so nearly infusible, and being unaffected by most acids and other chemical agents, it is applicable to a multitude of purposes, but it is attacked by caustic alkalies, and by the nitrates, especially of potassa and soda, as well as by metallic and other substances containing phosphorus.

The beautiful covering of pottery by platinum, has been already mentioned.‡

SEC. XXXVII.—PALLADIUM.

I. HISTORY AND NAME.—*Discovered by Dr. Wollaston, in 1803*, but the account of his researches was not given till July 4, 1805, when it was read before the Royal Society.|| It has since been examined, together with the associated metals, by Vauquelin, Berzelius, and other eminent chemists.

It was named after the planet *Pallas*, discovered by Dr. Olbers.

* E. Davy, Phil. Trans. 1817.

† I have an evaporating basin of pure platinum, which I find very useful; it is 8 inches broad at the top, and 1 inch deep.

‡ Vol. I, p. 290.

§ Dr. Wollaston exposed portions of this metal for sale, before any account was given of its origin; hence it was suspected to be an alloy, and M. Chenevix wrote two elaborate memoirs to prove that it was composed of platinum and mercury. Phil. Trans. 1804-5. Various other suggestions were made from different quarters, but no one now doubts that palladium is a distinct metal.

|| Transactions, 1805.

II. PROCESS.*

(a.) *To the neutral† nitro-muriatic solution of crude platinum,‡ (whether that metal has been separated or not by muriate of ammonia,) add prussiate (bi-cyanuret) of mercury; in a few seconds or minutes there will be a pale yellowish precipitate of pure prussiate of palladium.*

(b.) *This being ignited, the volatile ingredients are expelled and pure palladium remains.*

III. PROPERTIES.

(a.) *Malleable and ductile; color white, with a shade of gray; can scarcely be distinguished by the eye from platinum; harder than forged iron; from the file, acquires the brilliancy of platinum.*

(b.) *Sp. gr. 10.97 to 11.48—of the fused button 11.87; its true gravity probably falls little short of 12.*

(c.) *Infusible by the common blowpipe, or in an open vessel when heated above the point of melted gold, but with an intense heat it melts and the button is grayish white.*

(d.) *Among metals, an imperfect conductor of heat; conducts about as well as platinum; if the power of the latter is called 1, that of copper will be $2\frac{1}{2}$, and that of silver $3\frac{1}{2}$;§ rather more expensible by heat than platinum.*

(e.) *Melts, scintillates and appears to burn, under the compound blowpipe.*

(f.) *It cannot be doubted that its wire or leaf would be dissipated with the usual phenomena, by the electric or galvanic discharge, but I do not know that it has been attempted.*

* *Vauquelin's method of obtaining palladium.*—Place in the nitro-muriatic solution, (containing an excess of acid,) slips of bright iron; all the metals are precipitated, except iron itself; nitric and muriatic acids, successively applied, dissolve the iron, copper and lead; the residue is heated in a crucible, to remove the muriates of mercury, copper and osmium, and then it is treated by nitro-muriatic acid, which dissolves all the metals except iridium; the solution contains the muriates of platinum, palladium, rhodium, iron and copper; it is decomposed by muriate of ammonia, filtered and evaporated to dryness, to separate the muriate of ammonia and platinum; the residue is dissolved in water, acidulated by muriatic acid, and decomposed by ammonia, not quite sufficient to saturate the acid; a sub-muriate or chloride of ammonia and palladium precipitates immediately, in delicate silky needles of a rose color, which are washed with water, acidulated by muriatic acid; it is decomposed by heat, and affords pure palladium. This complicated process has been superseded by that of Dr. Wollaston, described in the text.

† It may be rendered neutral, either by the evaporation of the redundant acid or by an alkali or alkaline earth, or by mercury, copper or iron.—Wollaston's memoir, Phil. Trans. 1805.

‡ Which is very complicated and contains, besides platinum and palladium, copper, lead, rhodium, mercury, iridium, osmium, iron, &c.—*Thénard*.

§ Estimated by the wax melted upon them when heated.—Wollaston, Phil. Trans. 1805, p. 529.

IV. RELATION TO OXYGEN AND ACIDS.

(a.) *Not oxidized*, in any length of time, *when heated or even melted in the open air*; ignited in a state of minute division and exposed to a stream of oxygen gas, it becomes blue, but acquires no appreciable weight; still the color is removed by hydrogen, which fact favors the idea that it is an oxide.*

(b.) *Oxidized and dissolved by nitric acid*, with rather more difficulty than silver; more easily by nitrous acid, and no nitric oxide gas is evolved; the solution is of a beautiful red.

(c.) *Muriatic acid, at a boiling heat, acts on palladium*, so far as to acquire a fine red color; the same is true of the sulphuric which dissolves a little of the metal.

(d.) *The proper solvent is nitro-muriatic acid*, by means of which it forms much proto-chloride, a little per-chloride and nitrate of protoxide.

(e.) *Muriate of potassa or common salt forms, with the solution, an alkaline chloride of palladium*, with one equivalent of chlorine; it is soluble in water and in alcohol.—*H. and Berzelius.*

(f.) *The nitrate and other salts are decomposed by potassa, and other alkaline agents* and an orange colored hydrate appears, which becomes black by drying, and is decomposed by a red heat.

(g.) **OXIDES.**—According to Berzelius, *there are two*—the protoxide, composed of metal 86.94, + oxygen 13.06, and peroxide, metal, 76.92, + oxygen, 23.08.

Its equivalent is 56, and that of the protoxide 64.—The protoxide dissolves slowly in acids, even when wet.

V. COMBUSTIBLES.—*Sulphur combines readily with this metal*, which instantly melts when the sulphur is thrown upon it at a high heat; upon this fact is founded *Dr. Wollaston's method of obtaining palladium in a malleable state.* The prussiate is to be decomposed by heat, and the residuum combined with sulphur, and the fused sulphuret must be purified with borax and a little nitre; it is roasted on a flat brick at a low red heat, and when pasty, pressed into a flat cake; it is again patiently roasted till it is spongy, and the cooled ingot is gently tapped to condense the spongy surface; this is repeated with great caution till the cake will sustain harder blows, and will bear the flattening mill by which it is laminated.†

The sulphuret is white and brittle, and contains 22 per cent. of sulphur.

* Berzelius, Ann. de Chim. et de Phys. Vol. XL, p. 80.

† Dr. Wollaston, Phil. Trans. 1829, and Phil. Mag. and Ann. Vol. VI, p. 8. The palladium is brittle when hot, perhaps from sulphur; when fused without the sulphur, it however works with more difficulty.

VI. MISCELLANEOUS FACTS.

(a.) *Palladium is oxidized by melted potassa and nitre*, but less perfectly than the other metals that accompany platinum.

(b.) *It unites with the alkalies*; with the fixed, by fusion, with ammonia in the fluid form, and the solutions of the alkalies, to a degree, dissolve the oxide or hydrate.

(c.) *Palladium is precipitated from its solution, by all the metals except gold, silver and platinum.*

(d.) Precipitated, when neutral, by recent muriate of tin, of a dark orange or brown—a delicate test.

(e.) Green sulphate of iron throws it down in the metallic state.

(f.) Ferro-prussiate of potassa produces an olive colored precipitate.

(g.) Hydro-sulphurets and solution of sulphuretted hydrogen, give a dark brown precipitate.

(h.) *A detonating substance is produced by precipitating solution of palladium by neutral prussiate of mercury;* at 500° it explodes like gunpowder* but the light is visible only in the dark.—Wollaston.

(i.) *Spongy palladium ignites hydrogen*, like platinum.

VII. ALLOYS.—*Palladium readily forms alloys*; like platinum, even in minute quantity, *it whitens gold*; the alloy is harder, but less ductile than gold;† with silver, it forms a hard and gray alloy. Palladium is readily alloyed by platinum.

VIII. NATURAL HISTORY.—*Usually accompanies the ore of platinum*, and is dissolved in the nitro-muriatic solution; it is found with the Russian as well as the South American platinum.

Among the grains of platinum from Brazil, *Dr. Wollaston discovered grains of native palladium of a fibrous structure.*‡ Mr. Cloud, of the American mint, discovered palladium in some ingots of gold from Brazil.§ A mass of native palladium, weighing six pounds, from Sergipe, in Brazil, was shown at the Royal Institution, in Feb. 1826; this is the largest mass known.—H.

Remark.—*Palladium is evidently a very interesting metal*, and could it be obtained in abundance, it would prove of much utility; that it has been discovered and obtained at all, is a sufficient proof of the delicacy of modern chemical researches.

* Prussiate of mercury does not precipitate platinum, which distinguishes between it and palladium.

† A metallic surface composed of an alloy of these two metals, for the graduation of the grand circular instrument or the Royal Observatory, at Greenwich, was made by Dr. Wollaston. It resembles platinum, and is very hard.—H.

‡ Phil. Trans. 1809.

§ I have a piece of this alloy; its color is gray.

SEC. XXXVIII.—RHODIUM.

I. DISCOVERY AND NAME.—*Discovered by Dr. Wollaston; his memoir** contained all that was known of it till Vauquelin and Berzelius examined it,† and more recently Berzelius has given an elaborate memoir‡ upon it and the other metals associated with platinum.§ Its name is from *ρῶδον*, a rose, on account of the red color of its salts.

II. PROCESS.

(a.) The *nitro-muriatic solution of crude platinum*,|| after being precipitated by muriate of ammonia, still contains some of the ammoniacal muriate of platinum, and several other metals.¶

(b.) Bright zinc precipitates all the metals, as a black powder; among them are copper and lead, which are removed by washing the precipitate with warm dilute nitric acid.

(c.) The remnant, after being washed, is digested in weak nitro-muriatic acid, and there remains an undissolved portion, equal to nearly $\frac{1}{3}$ th part, chiefly an alloy of iridium and osmium.

(d.) The solution contains the muriates (or chlorides) of platinum, palladium and rhodium, and they are converted into soda muriates, by the addition of about $\frac{1}{3}$ th as much common salt as there was of the ore originally, and then the solution is gently evaporated.

(e.) The dry mass contains the soda muriates of the three metals named in (d.); those of platinum and palladium are removed by alcohol, and that of rhodium remains.

(f.) The soda muriate of rhodium is dissolved in a little hot water; and by repose of twelve hours, it crystallizes, in red rhomboidal crystals; the crystals are redissolved and a piece of bright zinc precipitates the rhodium, a black powder, equal to about $\frac{1}{15}$ th or $\frac{1}{16}$ th of the entire quantity of the ore.

(g.) From the solution of the soda muriate, ammonia precipitates a lemon yellow ammoniacal oxide of rhodium, which is reduced by heat to the metallic state.**

* Phil. Trans. 1804.

† Ann. de Chim. LXXXVIII.

‡ The numerous details which it contains cannot be embraced in an elementary work like the present.

§ Ann. de Chim. et de Phys. Vol. XL; undertaken by desire of the Russian government.

|| As this frequently contains mercury, which has been employed by the Spaniards to extract gold, Dr. Wollaston heated the crude platinum red hot, that the quicksilver might be volatilized.

¶ The color of the solution is due principally to iron, but is affected also by the strength and proportion of the acids; the metals usually present are platinum, rhodium, palladium, copper and lead.

** Berzelius, Ann. de Chim. et de Phys. Vol. XL, p. 73.

III. PROPERTIES.

(a.) *The black powder continued black when heated ; with borax it assumed a metallic aspect*, but appeared infusible ; it has since been melted in a powerful wind furnace.*

(b.) *Sp. gr. 11 ; brittle, hard ; not malleable nor ductile.*

(c.) *Like platinum fusible by arsenic and like palladium by sulphur ; both are expelled by heat, but the metal is not rendered malleable, as these two are, by the same treatment.*

IV. RELATION TO OXYGEN.

(a.) Although it is infusible, even in a fire maintained by oxygen gas, it can scarcely be doubted that it would both melt and burn under the compound blowpipe, but I am not aware that the experiment has been tried.

(b.) *Heated in the air it becomes a black oxide*, containing 100 parts metal, and 17.9 oxygen but it is insoluble in acids ; (Berzelius) it gives up its oxygen again, by heat, so that it has this characteristic of a noble metal ; the hydrate contains rhodium 75.9, oxygen 17.5, water 6.6 —According to Dr. Thomson it has two oxides ; the protoxide containing 44 rhodium, and 8 oxygen, and the deutoxide (of a yellow color) 44 rhodium 16 oxygen ; this statement admits 44 for the equivalent of rhodium.†

(c.) *Insoluble in acids even in the nitro-muriatic ; if alloyed with lead, bismuth or copper, it then dissolves in nitro-muriatic acid, and the muriate (the other metals being separated,) has a red color but does not crystallize, nor does the nitrate.*

(d.) *Rendered soluble in nitro-muriatic acid by previous fusion with bi-sulphate of potassa*, and by this means it is separated from minute portions of iridium and osmium.

(e.) By trituration with dry muriate of potassa or of soda, and exposure for some hours to a current of chlorine gas, rhodium was turned into a chloride ; soluble in a little hot water, but not in alcohol by which it was precipitated and washed.

(f.) Chlorine gas passed over rhodium forms two chlorides, one yellow and the other red.

V. ALLOYS *are easily formed with rhodium*, and it united with all the metals that Dr. Wollaston tried except mercury : with gold and silver, the alloys were malleable ; 4 parts of gold and 1 of rhodium did not perfectly melt ; 6 of gold and one of rhodium did not melt at all, and there was so little change of color that the mass might have been taken for pure gold. Steel receives a great increase of hard-

* Stodart and Faraday.

† As the results of Berzelius and Thomson do not agree, the subject must be left for the present undetermined. Berzelius thinks the black oxide is a mixture ; he has also described a brown oxide whose distinct existence is uncertain.

ness from even 1 or 2 per cent. of rhodium, and still it does not crack in forging or hammering.*

VI. MISCELLANEOUS.

(a.) Not precipitated from its solution by prussiate of potassa, or the muriate or hydro-sulphuret of ammonia, or by carbonate of potassa, soda or ammonia.

(b.) Pure alkalies precipitate a yellow oxide soluble in acids.

(c.) Salts of the deutoxide or peroxide are prepared by the action of acids, on the precipitate made by carbonate of soda, from the solution of the soda chloride, but they have been little investigated.

(d.) Rhodium is precipitated from its solution by silver, copper, and other metals, and yellow by the solution of platinum. Rhodium appears to be combined with the platinum in the ore.

REMARK.—A metal so little known and which the student will rarely see, cannot, in an elementary work, occupy an extended description; for many details omitted here, recourse must be had to the original memoirs of Wollaston and Berzelius, cited above.

SEC. XXXIX.—IRIDIUM.

I. HISTORY AND NAME.—*Discovered in 1803, by Mr. Tennant,† in the black residuum from the solution of the ore of platinum; it was the first observed of those metals that accompany platinum; discovered also in France, about the same time, by M. Descotils,‡ but the latter did not observe that another metal, osmium, is combined with the iridium; this compound has since been observed as a native alloy among the grains of crude platinum.§ The name Iridium, in allusion to the rainbow, (iris,) was given it on account of the changeable color of its muriate.*

II. PROCESS.

(a.) *We begin with the black insoluble substance, already mentioned, consisting chiefly of iridium and osmium.*

(b.) *These metals are separated by the alternate action of a caustic fixed alkali and an acid.*

(c.) *The black powder is ignited, for some time, in a silver crucible, with a large proportion of caustic soda or potassa; water then forms with it a deep orange or brownish yellow solution; much of the powder remains undissolved, and muriatic acid, by digestion with the residuum, forms a dark blue solution, becoming dusky olive green, and with heat deep red; by the alternate action of acid and alkali, the whole is dissolved.||*

* Eng. Quart. Jour. IX, 328.

† Phil. Trans 1804.

‡ Ann. de Chimie, Vols. XLVIII, XLIX, L, LII, LXXXIX. Descotils, Vauquelin, Fourcroy, &c.

§ Dr. Wollaston.

|| Some silica is dissolved at each operation, and is probably combined with the ore.—Tennant.

(d.) *The alkaline solution is chiefly of osmium, with a little iridium, which, by standing some weeks, it deposits, in thin dark flakes.*

(e.) *The acid solution is principally iridium, in the state of muriate, which imparts a red color to the triple compound of platinum and muriate of ammonia; it gives a dark brown precipitate, with a pure alkali, which during its solution in muriatic acid, produces the variety of colors already mentioned. The muriate of iridium has so intense a color that 1 part sensibly tinges 10,000 of water.*

(f.) *To obtain the muriate of iridium as pure as possible, the semi-crystallized mass procured by evaporation, after being dried on blotting paper, is redissolved in water, again evaporated and distinct octahedral crystals obtained.*

(g.) *The aqueous solution of these is deep orange red; muriate of tin, carbonate of soda, sulphuretted hydrogen and prussiate of potassa, gave no precipitate, but instantly destroyed the color; pure ammonia threw down the oxide, but by dissolving a little of it, became purple, and fixed alkalies had the same effect, only the color was yellow; all the metals that were tried, gold and platinum excepted, destroyed the color and threw down a dark or black precipitate of iridium.*

(h.) *The pure metal is obtained by heating the octahedral crystals of the muriate;* the volatile principles being expelled.*

(i.) *Also, by adding ammonia to the muriate, but not enough to saturate the excess of acid; the muriate or chloride of ammonia, which falls in a black powder, is calcined and affords the metal.† The muriate may be decomposed by zinc, which will precipitate the iridium.*

III. PROPERTIES.‡

(a.) *Color white; brittle; hard;§ of very difficult fusion; melted by a stream of oxygen gas received on burning charcoal; also by Mr. Children's great galvanic battery, which gave a very brilliant, white, but somewhat porous and imperfectly globular mass, weighing 7.1 grs.; sp. gr. 18.68;|| it is therefore nearly as heavy as gold, but inferior in weight to platinum.*

* The muriate of iron usually present may be previously removed by alcohol.

† See Thénard, 5th ed. Vol. III, p. 495; also Ann. de Chim. Vol. LXXXIX; this process is adapted to the accurate analysis.

‡ The black powder, heated by the blowpipe, affords metallic iridium, but not pure; still, as the osmium is volatile, it is probable that little of that metal would remain, and the compound blowpipe would doubtless cause the iridium to be still purer.

§ The rigidity and hardness of common platinum are supposed to depend upon iridium.

|| Which Mr. Children thinks below the truth, on account of the pores.—Phil. Trans. 1815, p. 370.

(b.) *Not acted upon by acids, and scarcely by the nitro-muriatic.*

(c.) *When oxidized, it unites readily with acids; its nitrate is red, and its sulphate as well as muriate is green or blue, according to its state of dilution; the precipitates obtained by alkalies are generally triple salts.*

(d.) *By nitre and by the fixed alkalies it is oxidized by the aid of heat, and an alkaline solution of a rich blue is obtained by the aid of water.*

(e.) *When oxidized, it unites with the earths, particularly with alumina.*

(f.) **OXIDES.**—From the changes of color in solutions of iridium the oxides have been *inferred to be numerous*, but it is probable that *some of them are owing to mixtures.*

(g.) From the native grains of platinum, a strong heat applied in an earthen retort raises a blue sublimate of oxide of iridium.—*Murray.*

(h.) **CHLORIDES.**—*This metal is said to combine with chlorine in four proportions, producing as many chlorides, and these combine with as many proportions of alkaline chlorides, forming the same number of double chlorides.*

(i.) *It is supposed that there are as many oxides as chlorides, each oxide forming different salts, and the sulphurets, made by passing sulphuretted hydrogen gas through the solutions of the chlorides (muriates) form sulphurets in the same proportions, the sulphur combining with the metal, and the chlorine with the hydrogen.*—*Berzelius.*

IV. ALLOYS.—*Iridium is easily alloyed with several metals.*

1. The alloy with lead is decomposed by cupellation, leaving the iridium upon the cupel.

2. The alloy with copper is malleable; when cupelled it leaves less iridium than in the former case.

3. With gold and silver it forms malleable alloys, or mixtures, not decomposed by cupellation, nor, in the case of gold, by quartation; when the silver and gold are dissolved by acids, the iridium is left.

V. MISCELLANEOUS.—The late elaborate memoir of Berzelius* has brought to light many new facts respecting iridium and the other metals that accompany platinum. A few of the most prominent I have cited, but the remainder, although important to a full history of the metal, involve too many details to be inserted in this work. To the general student they would not be interesting, and the analyst and professional chemist will resort to the original memoir. I will quote, in confirmation of the propriety of the name iridium, the follow-

* Ann. de Chim. et de Phys. Vol. XL.

ing remark of Berzelius: "Solutions of iridium may, without the aid of foreign matter, be obtained with all the colors of the rainbow."

SEC. XL.—OSMIUM.

I. HISTORY AND NAME.—*Discovered by Mr. Tennant in 1803;** examined by Fourcroy and Vauquelin;† by Wollaston,‡ and by Berzelius.§ *Its name, (from osm, odor,) alludes to the strong and peculiar smell emitted by its oxide; it resembles that of chlorine or iodine. Osmium is found only among the grains of crude platinum, always combined either with the other metals or with iridium in a peculiar alloy.*

II. PROCESSES.

(a.) *The alkaline solution*|| mentioned under iridium, (p. 385.) affords oxide of osmium by simply heating it with any acid; e. g. the sulphuric or nitric.

(b.) *Nitre 1 part, with 3 of the ore of iridium, being ignited in an open fire, till the materials are pasty and emit fumes of osmium; all that is soluble in water (in the least quantity that is sufficient,) is decomposed by sulphuric acid, equivalent at least to the alkali, and mixed with an equal weight of water; the fluid is rapidly distilled into a clean receiver, as long as osmic fumes come over, and the oxide, at first, incrusting the receiver and then running to the bottom, forms a globule, which on growing cold, crystallizes, and the water is also a strong solution of it.*¶

(c.) *Berzelius treats the alkaline mass with muriatic acid, to form a double muriate or chloride, and adds also a good deal of the nitric, which decomposes the muriates, (chlorides,) and by distilling $\frac{1}{2}$ or $\frac{1}{4}$ the osmium is obtained below a boiling heat; ** the fluid may then be acidulated with muriatic acid and decomposed by pure zinc, which precipitates the osmium†† in the form of a black powder.*

(d.) *The solution of oxide of osmium, shaken in a vial with mercury, becomes inodorous by forming an amalgam; the excess of mercury is removed by straining through leather; that which is in the amalgam being removed by distillation, the osmium remains, and after being washed, it is heated in close vessels, to give it the metallic lustre.*‡‡—Tennant.

* Phil. Trans. 1804. † Ann. de Chim. Vols. 48, 49, 50, 89.

‡ Phil. Trans. 1806, and 1829. § Ann. de Ch. et de Ph. Vol. XL.

|| Made with potassa or soda or nitre; it emits the peculiar odor in a degree when water is added even without acid. ¶ Dr. Wollaston. Phil. Trans. 1829.

** If pushed till the acid is concentrated, some muriate of iridium comes over.

†† Berzelius prefers to precipitate by mercury.

‡‡ During the solution of the crude platinum, some osmium is volatilized in the acid, which being condensed in a receiver, may be saturated with lime and the oxide of osmium obtained by distillation.

II. PROPERTIES.

(a.) *Receives a polish under the burnisher, but it is commonly seen in black powder or in a porous mass.*

(b.) *Sp. gr. 10, for the maximum, and 7 for the minimum.*

(c.) *Berzelius obtained it in the compact state, by passing its oxide, mixed with hydrogen gas, through a glass tube, heated red hot, in a space of about one inch; the osmium is precipitated and forms a ring, having a metallic lustre equal to that of the alloy with iridium.*

(d.) *Infusible at a white heat, although buried in a cavity in burning charcoal; fixed and unaltered, if air is excluded.*

(e.) *Heated with access of air it easily sublimes in a white crystalline or odorant oxide, which is soluble in water; the volatilized oxide of osmium is very penetrating, and after breathing its fumes for some hours, the sense of smell is lost for several days. The solution of the oxide is limpid and has a sweetish taste, but does not redden the blue vegetable colors; if the solution is concentrated, it stains the skin, indelibly, of a dark color.*

(f.) *The solid oxide is fusible as wax and has a caustic taste; it is decomposed by most metals, which destroy the smell and precipitate the metal.*

(g.) *The metal dissolves slowly, but entirely, in nitric acid; more rapidly in the fuming acid, aided by heat.*

(h.) *Nitro-muriatic acid dissolves it with great facility.**

(i.) *Its oxide has less affinity for acids than for alkalis; if heated in a silver cup with caustic alkali, it unites with it and water gives a yellow solution, from which acids expel the oxide of osmium with its peculiar odor.*

(j.) *OXYGEN unites with the metal at an elevated temperature; if compact and afterwards minutely divided it burns and sustains its own ignition.*

(k.) *OXIDES.*—*Berzelius states that there are three, containing 1, 2 and 4 equivalents of oxygen, and he is persuaded that there are even two more, composed of 3 equivalents of oxygen with 1 and 2 of the metal.†*

(l.) *He supposes that the oxide which gives the peculiar smell is a deutoxide; it produces cough, prolonged salivation and a pungent pain in the eyes.*

(m.) *He prepares this oxide pure, by igniting the osmium in a glass ball and passing a current of oxygen gas over it, when it burns, and the oxide is received in a solution of potassa, in which it forms distinct white crystals.‡*

* Like carbon, silicium and various other bodies, it becomes insoluble after calcination at a high degree of heat. Berz. † Ann. de Ch. et de Ph. V. XL. p. 270.

‡ Osmium placed on platinum foil and brought into the flame of a lamp produces a brilliant light like that of olefant gas; the osmium becomes an oxide, and its oxy-

(n.) *This oxide, at a temperature little elevated, burns most combustibles with disengagement of light; like nitre, it increases the combustion of burning coals.*

(o.) **CHLORINE—CHLORIDES.**—*No action between osmium and chlorine at the common temperature, but if the osmium is heated, there is formed a beautiful blue chloride, and with an excess of chlorine a red sublimed per-chloride.*

(p.) *The chloride deliquesces and crystallizes.* Osmium probably forms several chlorides, with different proportions of chlorine, corresponding to the oxides already mentioned. (Berzelius.) The chlorides of osmium form double chlorides with potassium and sodium.

(q.) **SULPHUR—SULPHURET.**—*Sulphuretted hydrogen decomposes the different chlorides or muriates of osmium and forms sulphurets, for an account of which I refer to Berzelius.* Sulphuret of osmium, burned in oxygen gas, produces a volatile oxide and a blue sublimate of sulphate of osmium.

III. ALLOYS.—*Osmium forms alloys with gold and silver; they are malleable and are easily dissolved in nitro-muriatic acid; the oxide of osmium rises in distillation. Osmium forms an excellent alloy with steel, and the addition of iridium makes it still more valuable.**

IV. MISCELLANEOUS.

(a.) *Infusion of nut galls is a delicate test of osmium; it strikes a purple and then a vivid and beautiful blue.*

(b.) Ammonia produces a yellow, and carbonate of soda the same, in a slighter degree; but lime gives a bright yellow.

(c.) *Alcohol decomposes oxide of osmium, depositing after some time black films.*

It has been already mentioned, that Dr. Wollaston discovered among the grains of native platinum, an alloy of osmium and iridium; its sp. gr. is 19.5, this exceeds that of native platinum, which is 17.7; the grains are about as large as those of native platinum but harder; they are not malleable and have a laminated structure, and a peculiar lustre.†

General composition of the platiniferous minerals.

It appears from the researches of Berzelius, that there is no difference between the platiniferous ores of Asia and America, except slight variations in the proportions.

gen burning the hydrogen, the metal, and the carbon of the flame reflect the light; chlorine directed into an alcohol lamp produces a similar result by developing carbon. Iridium, containing only a little osmium, increases the lustre of flame.

* Faraday, Phil. Trans. 1822.

† Phil. Trans.

The platiniferous sands contain small scales of *metallic iron*, besides an alloy of *platinum and iron* not only magnetic, but having polarity, and sometimes these grains will lift minute pieces of steel wire; they have a different composition from the grains that are not magnetic.

The principles of the platiniferous minerals, arranged in the order of their quantity, are *platinum, iron, iridium, copper, rhodium, palladium and osmium*.* The iridium and osmium are either alloyed with the other minerals, or in a distinct alloy with each other; in the former case they are dissolved with the platinum; in the latter they remain undissolved in small white brilliant scales. The following table will show the relative proportions of these principles in several cases.

	Uralian.			Colombia, S. A.
	Mag. grs.	Non mag.		
Platinum,	78.94	73.58	86.50	84.30
Iridium,	4.97	2.35		1.46
Rhodium,	0.86	1.15	1.15	3.46
Palladium,	0.28	0.30	1.10	1.06
Iron,	11.04	12.98	8.32	5.31
Copper,	0.70	5.20		0.74
Alloy, Osm. and Irid.			1.40	
in grains,	1.00			Quartz, 0.60
in scales,	0.96			Lime, 0.12
Insoluble		2.30		
	98.75	97.86	98.92	98.08
	Nische Tagilsk.		Goroblagodat.	

Remark.—Perhaps there is no instance in which the delicacy of modern analysis has appeared more conspicuously, than in the discovery of the metals associated with platinum. They are obtained by refined and troublesome processes; their properties are very curious, and some of these metals would be applied to use, could they be obtained in sufficient quantity.

* Mercury, in the South American ore is derived from the amalgamation used for obtaining the gold, which, as well as chrome and titanium, and perhaps copper appears to be accidentally present.

ORGANIC BODIES.

Introductory Remarks.

We have now finished the history of the ponderable elementary bodies. Since mineral substances, including the waters and the atmosphere, either mediately or immediately, afford support to both vegetable and animal bodies, it is obvious that the organic kingdoms can contain no element which is not found in the mineral. All that we can therefore expect, is, that by the agency of the vital principle, as well as of the laws of matter, organized bodies should produce compounds, formed from certain elements of the mineral kingdom. In fact, only a few of these elements are actually employed. In vegetables, oxygen, carbon and hydrogen, are all that are, in most cases, essential; nitrogen (or azote) exists in a few plants,* and these four elements are found in most animal bodies, the nitrogen being in them the most characteristic ingredient. The diversity of products in organized bodies is, in both kingdoms, produced by differences in the proportions, and in the mode of combination, in obedience to the vital principle, which often modifies or controls chemical and mechanical action.

Besides the elements above named, that are essential to organized bodies, there are others which are present in different cases, in greater or less quantity; such are phosphorus, sulphur, chlorine, iodine, bromine, potassium, sodium, calcium, silicium, magnesium, iron, manganese, &c. but generally they are in minute quantities; these elements exist in organized bodies, in various combinations, and the metals of the earths and alkalies are always in union with oxygen, and most commonly with an acid.

Both animal and vegetable bodies are decomposed with great facility, and readily pass into new combinations and new modes of existence.

Distinction between ultimate elements and proximate principles.

The ultimate elements have been already mentioned; the proximate principles are those compounds which, by natural laws, are formed in the organic bodies, during life, and are obtained by easy and simple processes or by natural occurrences, which permit the compound to appear, as it probably existed in the organized body.

Thus, gum and turpentine exude from, and concrete upon their respective trees and plants; volatile oils are distilled by immersing the plants in water, and they rise and are condensed with the aqueous vapor; they also evaporate spontaneously into the air; dense oils are often

* Vol. I, p. 194.

obtained by pressure, as from the sun-flower seed, and the olive and almond; animal gelatine is dissolved in hot water, and concretes on cooling, and albumen separates spontaneously, during the coagulation of blood, &c.

It is our object to ascertain the number and distinctive characters of all the proximate principles which exist in plants and animals, as well as the elements which they respectively contain, and their proportions and mode of combination.

Organized bodies are sufficiently distinguished by the following characters.

1. Composed of the same elements, united in different proportions.
2. Decomposed with facility, both spontaneously and by art.
3. In general, cannot be formed by art.
4. Decomposed at ignition and frequently below it.—Turner.

I. VEGETABLE BODIES.

Ultimate or destructive analysis.

Formerly this was effected by fire, by acids, and other violent agents, and although the complex results afforded some insight into the ultimate constitution, they gave no information as to the mode of combination, either proximate or elementary. Thus, wood burns in the open air and affords water and carbonic acid, indicating oxygen, carbon and hydrogen; and, if decomposed by ignition, in close vessels, with a proper place of efflux for gases, it affords carbonic acid and carbonic oxide, carburetted hydrogen, and empyreumatic acid* and oil; and charcoal remains in the vessel; these various things contain the elements before enumerated and no others; if nitrogen had been present, then ammonia or prussic acid would probably have been formed; adding however proof of the existence of only one element more, namely, nitrogen.

Accurate elementary analysis.

This is the result of modern research; it was introduced more than twenty years ago by Gay-Lussac and Thénard;† no part of practical chemistry is more difficult in the manipulations, although the principle of the experiments is very simple and intelligible. To burn or oxygenize the vegetable,‡ a substance is selected which easily affords oxygen; chlorate of potassa and peroxide of copper are commonly employed, and the latter is preferred because it gives up no oxygen, even at a white heat, unless by transferring it to the combustible, while the chlorate affords it easily, alone, at a low red heat.

* Acetic acid (pyroligneous) is a constant product of the distillation of vegetables, (the oily bodies alone excepted.) Empyreumatic volatile oil gives a peculiar odor, as when paper is burned; tar is also a product, especially in the distillation of wood.

† Improved and extended since, by Berzelius, Prout, Ure, and others.

‡ This method is applied also to animal substances.

The principle of these researches is, that by the nature and proportions of the products, we judge of the nature and proportions of the elements; by the agency of oxygen, the carbon will be converted into carbonic acid, and the hydrogen into water, and the nitrogen, if present, will remain as a gas. In every twenty two grains of carbonic acid, there are six grains of carbon, and in every nine grains of water, there is one grain of hydrogen; the remainder of the weight in both cases being oxygen; and if the substance under examination contained nothing besides carbon and hydrogen, their united weight will be found in the product; if the latter exceeds this weight, and especially if the substance employed to impart oxygen, has not lost so much of that body as we find of it in the carbonic acid and water, then, if there is no other product, we conclude that the substance contained oxygen equal to the difference in the two cases. If nitrogen is present, that will generally remain after the carbonic acid is washed out, and to avoid the danger of converting it into nitric acid, protoxide of copper is sometimes employed instead of peroxide.*

For the details of manipulation and apparatus, reference must be had to the original researches and to full accounts of them † in the larger works.

The vegetable substance, dried at 212° , or under an air pump receiver, with the aid of sulphuric acid, is made into a ball with the chlorate of potassa, or with the peroxide of copper which is now preferred, and being again dried as before, it is heated by a spirit lamp or by coals,‡ either in a copper or glass tube§ stopped at one end, and communicating with a mercurial apparatus; thus the gases are obtained. We may estimate the hydrogen, by calculation, after deducting the weight of the carbonic acid, from the entire weight which the tube has lost; the remainder is water, provided there is no other product; but we may collect the water by causing it to pass through muriate of lime and the increased weight will be due to it.

Should oxide of carbon be formed, in any case, it must be converted into carbonic acid by detonating it with half its volume of hydrogen and as much oxygen.

* The peroxide contains one fifth of its weight of oxygen; it may be prepared by decomposing the nitrate by heat, and igniting the residuum: Gay-Lussac prefers this process, but the oxide may be obtained also by calcining copper filings or scales with agitation, or by decomposing the bin-acetate by heat or by decomposing the sulphate by potassa in excess.

† Henry's Chem. 11th Ed. Vol. II.; Gay-Lussac and Thénard, in *Recherches Physico-Chimiques*, Vol. II.; Ann. of Phil. IV, 270; Faraday's Chem. Manip: p. 306; Phil. Trans. 1807; Ann. Phil. N. S and Vol. III. p. 308; Ann. de Ch. et de Ph. July, 1826, Vol. 32; Gay-Lussac's *Cours de Chimie*, Vol. II.

‡ Gay-Lussac prefers the latter.

§ Of about one third of an inch in diameter, or adapted to the quantity; green glass is preferred, on account of its more difficult fusibility.

General results of vegetable analysis.

1. The elements appear to be united in definite proportions and the proximate vegetable principles are compounds of chemical equivalents combined in definite and multiple proportions, in the same manner as in mineral bodies.

2. When in a compound containing oxygen,* carbon, and hydrogen, there is more oxygen in relation to the hydrogen than is necessary to form water, the substance is acid, and the volume of the oxygen used in the analysis will be increased.†

3. When there is less, the body is resinous, oily, or alcoholic, and the volume of the oxygen will be diminished.

4. When it is just sufficient, the substance is neither acid nor resinous; as starch, gum, sugar, &c. and the volume of the oxygen will not be altered.

The number of vegetable proximate principles exceeds forty, and some authors form their arrangement of them upon the facts that have just been stated.

I prefer one founded upon the natural properties or origin; the connexion by composition as relates to oxygen and hydrogen, is easily exhibited in a tabular view and may be subjoined.

VEGETABLE PROXIMATE PRINCIPLES.

SEC. I.—GUM‡ AND MUCILAGE.

I. PHYSICAL PROPERTIES.

(a.) *The gum Arabic and the gum Senegal are good examples; the solution is called mucilage and the solid substance gum.*

(b.) *Gum is somewhat brittle; semi-pellucid; colorless or variously tinged; Sp. gr. 1.31 to 1.48; inodorous; tasteless; pulverizable; light often destroys the yellow color; the pieces of gum Arabic are small, those of Senegal often as large as a partridge's egg.*

II. CHEMICAL PROPERTIES.

(a.) *Soluble indefinitely in hot and cold water; solution viscid and smooth; if strong, ropy and thick; the gum is recovered by evaporation and is again soluble; it is hygrometric, attracting water from the air, and loses weight by drying at 212°.*

(b.) *Solution little altered by keeping, but eventually sours, acetic acid being formed.§*

(c.) *Does not suffer the vinous fermentation, even with yeast and warmth.||*

* All vegetables do not contain oxygen.

† Because carbonic acid gas will be added, and thus the oxygen gas will be rendered impure.

‡ The word gum, in the language of commerce and the arts, includes many resins and balsams.

§ Probably prevented, by blending with it oil of lavender and corrosive sublimate, in small quantities, since even paste of flour, with those additions, will keep for years as I have observed, (after Dr. Macculloch.)

|| It becomes offensive; when united with sugar, it easily ferments.

(d.) *Insoluble in alcohol, and precipitated by it* from its aqueous solution which becomes milky,* and thus *alcohol is a test of gum*; insoluble in ether and in oils, fixed or volatile.

(e.) *Employed to produce emulsions*, viz. opake mixtures of oil with water, also of resins and balsams.†

(f.) *Combines with several metallic oxides*; precipitated by red sulphate of iron, a brown semi-transparent jelly; sub-acetate of lead, (Goulard's extract,) gives a copious, dense, white precipitate, consisting of 38.25 parts oxide of lead and 61.75 gum; the acetate has no sensible effect; the per salts of mercury and iron are the most efficient precipitants.—*Thomson*.

(g.) *Soluble, without change, in pure alkalies and in alkaline earths*, and precipitated from this union by acids.

(h.) *Very dilute solution of gum is precipitated by silicated potash*, being first rendered opake; it thus forms a very delicate test; the effect is supposed to arise from the combination of silica with lime but does not occur except in the solution of the lighter colored specimens.‡

(i.) *Readily combines with sugar*, and the compound solution remains transparent, after gentle evaporation; alcohol separates some of the sugar, and the remaining compound resembles the substance of which wasp nests are composed.

(j.) *Dissolved by diluted, and decomposed by concentrated acids*; vegetable acids dissolve it without alteration.

(k.) *Strong sulphuric acid chars gum*, and produces water and acetous acid, and traces of tan.

(l.) *Nitric acid elicits no carbon*, but forms oxalic, malic and mucous or saccholactic acid.||

(m.) *Muriatic acid slowly changes gum into acetous acid*.

(n.) Chlorine gas passed through a solution of gum converts it into citric acid.

III. COMPOSITION.—42.23 carbon, 50.84 oxygen, 6.93 hydrogen, the two latter in the proportions to form water.—G. L. With these proportions those of Berzelius very nearly agree. Dr. Ure found carbon, 35.25, oxygen, 58.90, hydrogen, 5.85. Gum, thoroughly dried, lost 12.4 parts,§ and contained carbon, 41.4, water, 58.6, or oxygen, 52.09, hydrogen, 5.51.

* More water renders it clear again.

† A strong solution of gum is rubbed with twice its weight of olive oil, and the water is added by degrees, with constant rubbing.

‡ Oxalic acid also produces a precipitate, on account of the lime, which however does not appear to be an element of gum, but rather of a calcareous salt contained in it.

|| Which appears to be characteristic of gum; no substances produce saccholactic or mucous acid with nitric acid, except gum and sugar of milk; 2 parts of nitric acid and 1 of the gum should be used.—G. L.

§ Supposed to be per cent.

Most chemists regard gum as a ternary compound of carbon, oxygen, and hydrogen; some as a compound of carbon and water; the former opinion seems the more probable.

Dr. Thomson, regarding gum as having a definite constitution, attributes to it

6 equiv. of carbon,	36	40
6 " oxygen,	48	53.34
6 " hydrogen,	6	6.66
	90	100.

which comes very near the result of Dr. Prout.—H.

IV. KINDS AND SOURCES OF GUM.—Principal varieties, *gum arabic* and *senegal*, *gum tragacanth*, *gum* of the cherry, peach, and other fruit trees, and the *mucilage of the leaves, roots, seeds, &c.* of plants.

(a.) *Gum Arabic in Arabia, and Senegal in Africa exude from the Mimosa nilotica.* Cairo and Alexandria are the principal marts; but most of the gum used in Europe since the beginning of the sixteenth century, has come from the Senegal country.

(b.) Several species of *Mimosa* grow along the Barbary coasts in sands; trees eighteen to twenty feet high; gum exudes after the rains in the middle of November; hardens in a fortnight in beautiful roundish drops; no clefts are made for it to flow through; 1,200,000 lbs. are sold yearly to Europe from Senegal.

The Moors live on it entirely in harvest time; 6 oz. support a man a day; it is mixed with milk, animal broths, and other fluid food.*

(c.) *Gum tragacanth*, from the *Astragalus tragacantha*, a thorny shrub growing in Candia and other islands of the Levant; exudes about the end of June, from the stem and larger branches; is in white, almost opaque vermiform pieces; not easily dissolved in water; much stronger than gum Arabic, mixed with paste to give it strength.†

(d.) *Gum or mucilage is contained also in very many plants; principally in the seeds and roots, but also in the stalk, bark, and leaves; often in combination with fecula, sugar, resin, &c..*

(e.) *Most of the bulbous roots and fleshy leaves contain it; flax seed, quince seed, onion, garlic, bark of the slippery elm, Hyacinthus non scriptus, Althæa officinalis, (marsh mallow,) Malva sylvestris, (common mallow,) many fuci, most lichens, and generally, the smooth, slippery seeds,‡ &c.*

* Aikin, Vol. II. p. 110.

† Swells prodigiously and softens in cold water, without being much dissolved; boiled in water gives great viscidility, and it even gelatinizes; muriate of tin gives a firm coagulum with it; is not affected by red sulphate of iron and silicated potash, and thus differs from gum Arabic; it looks like twisted threads, and is seldom free from visible impurities; it has a tough, horny consistence, and is difficult to pulverize. It contains also the principle (analogous to gum) to which the name bassorin has been given.

‡ It exists in the leaves of the comfrey and mullein, and in the whole of the marsh mallow.

(f.) *The vegetable is boiled in water which becomes glutinous if there be much gum*; after subsidence it is evaporated to a syrupy consistence, and 3 parts of alcohol precipitate the gum.

(g.) *Mucilage of hyacinth*, (blue bells or hare bells *Hyacinthus non scriptus*.) 1 pound of the roots, when dried, produce 4 oz. of the powder; macerate in 5 parts of water; after pressure, the residue is treated in the same way; after subsidence, *it is evaporated to dryness in the open air*; the vernal squill, (*Scilla verna*,) and white lily, (*Lilium candidum*,) afford the same, and *all these can be substituted for gum Arabic, and so may the gum from the lichens*.*

(h.) Gum exudes from natural or artificial cracks in the peach, plum, cherry, apricot, and other fruit trees; it is generally of a fine amber color and in larger masses, softer and more fusible than gum arabic which it closely resembles in chemical properties. Vegetable jelly appears to be gum combined with a vegetable acid.†

V. USES.

(a.) *Gum tragacanth, when soft and pulpy*, in consequence of water's standing on it, *is easily mixed with other mucilages*; can be spread thin over any surface; mixed with paste, dries into a firm cement, and is *much used in book binding*.

(b.) *Gum arabic solution is considerably adhesive*, where there is not dampness; it is clean, convenient and easily kept; thin solution lightly spread over silk ribbons, linen, &c. with a brush imparts a fine gloss; hence, rain spots such articles.

(c.) *Principal use of gum, is to furnish a thick viscid fluid with which the mordants and colors are fixed in calico printing*; it prevents their running on the cloth.

(d.) *Gum is a nutritious food*, and exists in many things which we eat.‡

(e.) *In medicine not active*; used for its lubricating qualities; but the virtues of many medicines depend on a gummy matter,§ *used as a demulcent*—mucilage of gum arabic is the basis of the mixtures usually employed to allay coughing and it is prescribed in other cases, to counteract internal irritation.

(f.) *In Pharmacy, used to suspend heavy powders in water*; to give tenacity to substances made into pills, &c.||

* Some of them grow abundantly on forest and fruit trees, and in the north of Europe and America often 1 foot or more long, and sustain deer, &c.; the mucilage is extracted by boiling, &c. See Lord Dundonald's process, Phil. Mag. Vol. X. p. 293, and Murray, Vol. IV. p. 122.

† Dr. Bostock gave the name *cerasin* to the gum tragacanth, cherry tree gum, &c.

‡ It is one of the articles which a traveller in sterile regions, or on the ocean, might take with him advantageously, because it contains much nutriment in a small compass.

§ Murray.

|| Mur. Mat. Med. V. 1. p. 384.

SEC. II.—RESINS.

I. PHYSICAL PROPERTIES.

(a.) *Generally concrete ; color commonly yellow or brown*, and have a peculiar lustre called the resinous ; brittle when solid ; heavier than water, sp. gr. from 1.0180 to 1.2289.

(b.) *Non-conductors of electricity ; by friction exhibit the negative or resinous electricity ;* odorous and sapid, or inodorous and insipid ; fracture smooth and conchoidal ; generally soft or easily impressed.

II. CHEMICAL PROPERTIES.

(a.) *Easily fusible*, become concrete on cooling and are found unchanged ; not volatile, *but with an increased heat emit essential oil*, and the more, the more the resin is soft or fluid.

(b.) *Heated in close vessels yield the usual products of vegetable distillation* and a brilliant spongy charcoal ; they contain less hydrogen than volatile oils.

(c.) *Burn in the air with much yellow flame and smoke*, and a peculiar fragrance ; aqueous vapor rises and a fine charcoal which is a *pure lampblack*, is received on suspended stuffs.*

(d.) *Insoluble in water* and in most watery fluids.

(e.) *Soluble in alcohol, especially if hot*, forming a clear but colored solution ; alcohol of sp. gr. 0.835 dissolves $\frac{1}{4}$ of its weight at 60° F.—H. *most of the resin is precipitated by water*, and is pulverulent and unaltered.

(f.) *Soluble in sulphuric ether and in the fixed and essential oils*, especially the latter.

(g.) The alcoholic solution, evaporated, gives the resin unchanged.

(h.) *Solution in ether and essential oils is precipitated by water.*

(i.) *Solubility* of the more difficultly soluble resins is *promoted by camphor*.

(j.) Among the fixed oils, the drying oils are particularly employed for the solution of resins, and among the essential oils, the oil of turpentine.

(k.) *Fixed alkalis, by long boiling, dissolve powdered resins ;* 100 parts of rosin with $8\frac{1}{2}$ of potassa, form a good soap ; carbonates (even the carbonate of ammonia) do the same, only less actively, and the carbonic is in all such cases evolved ; the compounds are saponaceous ;†

* Vol. I. p. 357.

† Gay-Lussac, (Cours de Chimie, Vol. II. p. 30.) says—" Les résines se comportent comme des acides ; nous regarderons cette résine comme le type des autres et comme un acide ;" because it saturates the alkalis, and when they are saturated by an acid, the resin is recovered unchanged. Although sustained by such high authority, I cannot but regard the prevailing mode of calling every thing an acid, which saturates a base, whatever may be its properties in other respects, as a departure from sound logic and as tending to break down all useful distinctions between acids and other substances. Laugier objects to Gay-Lussac's use of the word resin in this sense. (Cours de Chimie, Vol. III. p. 257.)

the alkaline solution is clear and bears dilution with water without decomposition.

(l.) *These solutions are decomposed by acids and resin is precipitated*; rosin, mixed with soap by the boilers, is dissolved and imparts the yellow color and peculiar odor.

ACIDS act on resins.

(a.) *The nitric*, with long continued and repeated digestion, *produces* a deep yellow solution which precipitates gelatine, and therefore contains *tannin*; the resin before solution becomes a pale orange colored brittle body and then appears to be intermediate between extract and resin; the solution, which is permanent in the air, becomes turbid by water.

(b.) *Tannin is produced in much greater quantities if the resin have been slightly charred*, either by heat or by sulphuric acid; nitric acid acting on charcoal alone, produces more tannin than the whole weight of the charcoal.

(c.) *Oxalic acid is not produced in any case in which tannin is formed*; hence resins are distinguished from mucilages, gum resins, &c. which yield oxalic acid by the agency of this acid.

(d.) *Concentrated sulphuric acid dissolves powdered resin*, very quickly; the solution is of a transparent yellowish brown, and of an oily appearance; becomes darker if the digestion is continued; sulphurous acid gas is exhaled, and at the end of some days, a black porous coal remains, weighing one fifth or one third of the resin, while by incineration, in close vessels, hardly $\frac{1}{10}$ of the weight of the resin is obtained in the form of charcoal.

(e.) *Water decomposes the sulphuric solution*; the precipitates resemble resin the more, the earlier they are made, and charcoal the later; tannin is produced in one stage of the process.

(f.) *Acetic acid dissolves resins by digestion*, and water throws them down without change; resin and gluten may be thus separated; the acid dissolves both, but the gluten is not precipitated by water.

(g.) *Resins unite, by fusion, with sulphur and phosphorus*, but with difficulty.

(h.) *Volatile oils, by exposure to air, become inspissated, and approach to the nature of resin*; benzoic or camphoric acid is also formed; resins are thought by some to be volatile oils, deprived of a portion of hydrogen and combined with some oxygen.

III. COMPOSITION.—*All authors agree, that carbon, oxygen and hydrogen, are the elements*; but there is considerable difference in the proportions found by different analysts, as appears from the following table, cited from Dr. Henry.

	Gay-Lussac and Thénard.*	Dr. Ure.	Thomson.†	
Carbon,	75.944	75.	63.15	48.98
Oxygen,	13.337	12.50	25.26	48.98
Hydrogen,	10.719	12.50	11.59	2.04
	100.	100.	100.	

Resin dried at 276°,
with the loss of both
water and some es-
sential oil.

The two first nearly agree, and they correspond with about 15 equiv. of carbon = 90 + 2 of oxygen = 16 + 13 of hydrogen = 13 = 119. We cannot, however, entirely rely upon this conclusion. It appears that in the resins, the hydrogen is in greater proportion than to form water.

IV. KINDS AND SOURCES OF RESIN.

RESIN is a very important and abundant vegetable product; often combined with other principles, particularly with essential oil.

1. *Resin exudes spontaneously, or from wounds in trees*, or is deposited in the interstices of the wood, or in particular vessels, or in the green matter of leaves, which is a kind of resin; there is so great a variety of resinous substances, that it is impossible to enumerate them all; they may be divided into *resins, balsams, and gum resins*.

(a.) *Resin is the concrete residuum of the distillation of turpentine*.—The juice of the different species of pine, consists chiefly of resin and essential oil of turpentine; the principal kinds are *Pinus Abies, sylvestris, Larix* and *balsamea*.†

(b.) *Common turpentine is from the Pinus sylvestris*, (Scotch fir.)

(c.) *Venice turpentine*, more thin and aromatic, is from the *Pinus Larix, larch*.

(d.) *Strasburgh turpentine*, from the *Pinus Picea*, (silver fir.)

(e.) *Canadian balsam*—*Pinus balsamea*.§

(f.) *Carpathian or Hungary balsam*—*Pinus Cembra*, (Siberian stone pine.)

(g.) *Chio turpentine*—from the shrub *Pistacia Lentiscus*.

(h.) *Burgundy pitch*—Norway spruce fir and the larch.

(i.) *Thus or common frankincense*—Norway spruce.

(j.) *Common turpentine*|| is obtained by exudation and hardening of the juice flowing from incisions in the pine trees.¶

* Cours de Chimie, &c.

† Ann. Philos. XV.

‡ Jour. de Phys. Tome XXI.

§ Balm of Gilead Fir, Aikins.

|| The ordinary American turpentine is extracted chiefly from the *Pinus palustris* of Willdenow and Pursh, (*P. australis*, Michaux, arb. for. 1, p. 64,) which grows abundantly in the Southern States. All the trees mentioned in the text, except the *Pinus balsamea*, are natives of Europe.—J. T.

¶ In France, a tree in which incisions are made every year, often yields from six to twelve pounds, and lasts one hundred years; the old holes grow up, although sometimes eighteen inches wide and two or three deep; the turpentine that concretes in winter around the incision, is called *Barras* or *Galipot*; it contains less oil than that which collects in the summer; it is mixed with suet to make *flambeaux*.

(k.) Oil of turpentine, is distilled in an apparatus like the common still; water is placed with the turpentine, and the residuum and product exceed the original weight.*

(l.) Rosin is called *Brai sec*, by the French.†

(m.) Tar is melted out from the resinous trees by a smothered fire, either covered with turf like a coal pit, or in egg shaped furnaces.‡

(n.) Pitch is tar inspissated by boiling.§

2. MASTICH.—From the *Pistacia Lentiscus* in the Levant, especially Chios.|| Best mastich is in roundish tears, hard and brittle.

3. SANDARACH.—From the *Juniper communis*.¶

4. ELEMI.—Supposed to be from the *Amyris Elemifera*, from South America.**

5. ANIME.—From the *Hymenæa Courbaril*, of North America, Brazil, and New Spain.††

6. TACAMAHAC.—From the *Populus balsamifera*, of Canada.

7. LADANUM OR LABDANUM.—From the *Cistus creticus*, a fragrant shrub which grows in the mountains of Syria and Candia, and in the Levant.

8. BOTANY BAY RESIN.—From the *Acarois resinifera* of a yellow color.

9. Lac‡‡ exudes and concretes in consequence of the puncture of an insect; this is the stick lac.

(a.) Seed lac is this concretion granulated, picked and boiled in water.

* Therefore, some water is probably combined; if distilled without water, some good oil is obtained, but it soon becomes empyreumatic, and the resin is decomposed; 250 lbs. of good turpentine produce 60 lbs. of the oil.

† Common rosin, boiled for a while with water, forms the substance used by musicians to put on their strings. Rosin, kept in fusion some time, becomes blacker and more brittle, and is called colophony.

‡ In France and Switzerland ten feet high and five or six wide; upper orifice narrow; fire begins at top and the orifice is finally closed; 10 or 12 per cent. of tar are obtained from common pines, 1-4 from the red wood and knots; lamp black collects on the stones. Tar water derives its virtues chiefly from the pyro-acetic acid and empyreumatic oil.

§ It is done near London in a still to save the acid and oil, (Alkins).—Still of 600 gallons works 18 or 20 barrels of tar in 8 hours, = 10 barrels pitch, or 22 cwt. and 176 gallons of oil, and 40 of acid; the oil is used in coarse painting and the acid in forming mordants for calico printing.

|| Softens in the mouth, chewed in Turkey to sweeten the breath and strengthen the gums; thence its name of mastich. Solution in alcohol and that in essential oils much used as a varnish, alone, or with other resins.

¶ Similar to mastich; soluble in alcohol and in oils; much used in varnishing; pleasant smell; nearly tasteless.

** In large greenish masses; strong odor like fennel; costly; used for liniments and varnishes.

†† So much resembles copal that it is often sold for it or mixed with it; soluble in alcohol; it is chewed by the natives; never used in Europe; sometimes used in varnishes; brought in small tears or in larger masses.

‡‡ The *Coccus Lacca* fixes itself on the twigs and extreme branches of the *Banyan fig*, the *Rhamnus Jujuba*, or *Biher*, and on other trees in the East Indies;

Lump lac is the latter melted.

(b.) *Shell lac* is cast from the stick lac.*

(c.) *Lac consists chiefly of resin and contains coloring matter with vegetable gluten and wax.* Mr. Hatchet found the three sorts of lac to have the following composition.

	Resin.	Coloring Extract.	Wax.	Gluten.
Stick lac, - - -	68.	10.	6.	5.5
Seed lac, - - -	88.5	2.5	4.5	2.
Shell lac, - - -	90.9	0.5	4.	2.8

(d.) *Cold alcohol dissolves the greater part of lac.*

(e.) *Water dissolves the coloring matter.*

(f.) *Soluble in aqueous solution of Borax.†*

10. COPAL.

(a.) *A peculiar resin from South America and the East Indies.*

(b.) *Hard, brilliant, transparent, yellowish and pulverizable.*

(c.) *Sp. gr. 1.04 to 1.13; highly electrified by friction; often contains insects and resembles amber very strongly.*

(d.) *The composition of copal is almost exactly what has been already stated for the resins.*

(e.) *Varnish of copal is tough, firm, transparent, and admits of a high polish; the method of preparing it belongs to the arts, but a few facts may be mentioned.*

METHODS OF DISSOLVING COPAL.—*Not soluble in water, nor easily in alcohol, ether, and essential oils.*

1. Soluble under pressure, or by digestion at 150° in oil of turpentine.

2. After torrefaction, soluble in linseed oil, that has been discolored by light.

3. In the purest and strongest alcohol.‡

deposits its eggs and glues them to the branches by a red semi-pellucid liquid, which finds the insect a cell and the egg an envelope; it is a bag full of a beautiful red liquid which supports the insect till it eats through, leaving a resinous mass which is the stick lac.

* It is melted in a canvass bag, pressed through when fluid and formed into thin layers by congealing on the outside of a plantain tree prepared for the purpose.

Best lac comes from *Akam* but the uncultivated mountains on both sides the Ganges abound with it.

Stick lac contains the most of the coloring matter, and shell lac the least.

† Borax, 20 grs. Lac 100, water 4 oz., mixed with lamp black forms Indian or Hindoo ink, which is also a varnish. Shell lac in India is cut into beads, necklaces, &c.; it is the basis of the best sealing wax; (proportions, lac 54, turpentine 54, wax 3, vermilion 30; or lac 4, Venice turpentine 2, rosin 2; red lead and vermilion color the red wax, and lamp black the black;) of hard Japan varnishes, of lacquer, hence the word lacquering. Stick lac is a dye. Sand melted with lac is used in India for grindstones; corundum with lac is used for grinding and polishing gems.

‡ Add to powdered copal, liquid ammonia, till the swelling ceases, and it becomes a clear consistent mass, heat it to 95° Fah. and add it in successive portions, to cold strong alcohol; a colorless and perfect varnish is obtained.—*J. J. Berzelius.*

4. 2 oz. copal, 4 liquid ammonia, 1 pint of oil of turpentine; soluble by a regular heat with some pressure.

5. In camphorated alcohol, or 4 oz. copal, $\frac{1}{2}$ oz. camphor, 1 pint alcohol with a regular heat.*

6. When kept suspended in oil of turpentine or of alcohol, with some pressure.

7. If melted, it is dissolved by dense and volatile oils† dropped upon it;

8. By ether, with time and agitation.

Remark.—The common copal varnish is made by a previous melting and torrefaction, with the subsequent addition of linseed oil and oil of turpentine; it is occasionally adulterated with animé, mastich, sandarach, &c.

11. AMBER.—*Of vegetable origin*‡ although found in gravel, sand, &c.;§ *very analogous to resins* although differing from them and all bodies in some particulars.

(a.) *Resembles copal*; sp. gr. 1.06 to 1.10, odorous by heat or friction and highly electric.||

(b.) *A peculiar crystalline acid*, the succinic, is *sublimed from it* by heat;¶ burns with flame.

(c.) *Amber is only partially soluble in alcohol*; soluble in caustic potash.

(d.) *If roasted, it is soluble in fixed and volatile oils*, and both are used to form amber varnish.

(d.) *Sulphuric acid acts with energy*; *nitric with violence*; artificial musk results from an action of this kind; pulverized amber detonates in melted nitre.

(e.) *By distillation, amber affords a peculiar oil*, colored and empyreumatic; but repeated distillations, (or one, if performed in a water bath,) afford it limpid;** it is about two thirds the weight of the amber, and with liquid ammonia and potash, it anciently formed the remedy called *Eau de Luce*.

(f.) *Amber burns with spitting and frothing* and the liquefied drops rebound; those of copal flatten.—Hauy.

(g.) Dr. Ure found amber to be composed of carbon 70.68 oxygen 17.77 and hydrogen 11.62.

* Camphor is a great auxiliary to oil of turpentine in dissolving copal; copal and camphor by trituration become a soft mass, and remain long so in the air.

† Especially by oil of Lavender and rosemary, and by oil of turpentine; volatile oils aid each other.

‡ It often contains insects in fine preservation, thus proving that it has been soft and has gradually hardened; the insects are said by Jussieu not to be European.

§ Found also in lignite.

|| The name electricity is from the Greek *ἤλεκτρον*.

¶ See vegetable acids.

** Succinic acid is removed by washing; a black coal remains from the distillation of amber; it is the basis of a varnish.

Besides the above resins there is *gum hederæ* which exudes from the ivy ; also the green coloring matter of leaves and of almost all vegetables ; it is insoluble in water but soluble in alcohol ; chlorine develops the resinous properties in greater perfection ;

(h.) Berzelius found in amber essential oil, two resins, (one of them insoluble in cold alcohol) and the succinic acid.

USES OF RESINS.

No resin is fit for food.—In forming varnishes, generally more than one resin is dissolved ; varnishes are made with oil or spirit, and the oils are either expressed or volatile, commonly drying linseed oil or oil of turpentine. Resin or rosin with mastich is boiled in linseed oil, and oil of turpentine is added to accelerate the drying ; copal is often used in the fat varnishes and the solution of this, or of mastich is frequently mixed with colors as they aid in preserving the body, the tint and the lustre. Varnish of oil of turpentine is made with mastich, and copal. *Spirit varnishes dry readily but are apt to crack* ; they are made with mastich, sandarach, lac and copal or some mixture of them. Mastich or sandarach, alone or mixed, forms a colorless varnish with alcohol ;* turpentine prevents the varnish from cracking. Lac forms a colored varnish ; it is used where color is of no importance or even of advantage, as in lacquering brass.

Asphaltum, a mineral resinous body, is used as the basis of a black varnish.

BALSAMS.

(a.) *Balsams, in the popular and pharmaceutical sense, are resins, containing so much volatile, oil as to be fluid or semi-fluid.*

(b.) *They belong to the turpentine, although all turpentine are not called balsams.*†

* Varnishes.—Thénard.

	Spirit Varnish.	
Strong alcohol,	- - - - -	32
Mastich,	- - - - -	6
Sandarach,	- - - - -	3
Venice turpentine,	- - - - -	3
Glass coarsely pounded,	- - - - -	4
	Essence Varnish.	
Mastich powdered,	- - - - -	12
Turpentine,	- - - - -	1½
Camphor in pieces,	- - - - -	3
White glass powdered,	- - - - -	5
Spirits of turpentine,	- - - - -	36
	Fat Varnish.	
Copal,	- - - - -	16
Linseed oil,	- - - - -	8
Spirit of turpentine,	- - - - -	61

† Balsam was originally the juice of the *Amyris gileadensis*, but the term was extended to all fragrant substances of this kind.

BALSAMS, in chemical language, mean compounds of benzoic acid and resin, with sometimes a portion of essential oil. There are two classes of balsams, *liquid* and *solid*.

As the balsams do not form a distinct proximate principle, but consist of several united, it is not necessary in this work to describe them minutely. The following general notice will be sufficient, as their constituent proximate principles have or will come under review.

(a.) Melt and exhale Benzoic acid* and oil; combustible.

(b.) Soluble in alcohol, ether and volatile oils; the alcoholic solution decomposed by water.

(c.) Odorous; decomposed by alkalies which combine with their acid; the acid is partly extracted by water. They exude from wounds or cracks.

LIQUID BALSAMS.†

1. Balsam of Copaiba.

2. " Mecca, Opobalsam or Balm of Gilead.

3. " Peru.

4. " Tolu.

5. " Styrax, viz. liquid styrax or liquid amber.

The liquid or semi-fluid balsams, frequently become concrete by age.

SOLID BALSAMS.

1. Benzoin.

2. Storax.

3. Dragon's Blood.

For the reasons already stated, I merely name these substances, and refer for their description to books on the arts and the materia medica.

Dragon's blood, is in request, because it makes with alcohol a red varnish and in chemistry Benzoin is always used to afford the Benzoic acid.*

GUM RESINS.

(a.) Not a distinct proximate principle; contain chiefly gum and resin, with sometimes wax, gluten and volatile oil.

(b.) Belong to medicine and the arts, but are worthy of being mentioned.

(c.) Often active in taste, smell and medical power.

(d.) Exude from trees and plants, and become inspissated.

(e.) Alcohol dissolves the resinous,—water, the gummy part; proper solvent proof spirit; water precipitates the resinous part.

(f.) Generally soluble in boiling alkalies.

* See the vegetable acids.

† It is said, that some of these do not contain Benzoic acid, and are therefore merely turpentine, but, as I am not able to say, with precision, which are in this condition, they are allowed to stand above, as they are commonly classed.

PRINCIPAL GUM RESINS.

Galbanum.	Gamboge or Gungutt,
Ammoniac.	Myrrh.
Olibanum.	Sagapenum.
Asafoetida.	Euphorbium.
Scammony.	Aloes.
Opopanax.	

GALBANUM.

From the *Bubon galbanum*, a perennial umbelliferous plant of Ethiopia.

Composition—resin 66.86, gum 19.28, with volatile oil, &c.

GUM AMMONIAC.

Comes from the East Indies, from an umbelliferous plant, but not known what species.

Composition—resin 70, gum 18.4, glutinous matter 4.4, water 6.

OLIBANUM—Frankincense of the ancients.

(a.) From Turkey and the East Indies, from the *Boswellia thurifera*, or *Juniperus lycia*.*

(b.) On a heated body it is fragrant.†

(c.) Alcohol dissolves three fourths, and water three eighths.

Remark.—Olibanum is not the frankincense of the shops; this is said to be from the turpentine tree.

ASAFOETIDA.

From a large perennial umbelliferous plant, the *Ferula Asafoetida*, which grows in the mountains of Persia and Arabia.

Smell very fetid and diffusive; ‡ taste acrid and nauseous.

Composition—resin 65, gum 19.44, bassorine§ 11.66.

SCAMMONY.

From the root of the *Convolvulus scammonia*, a climbing plant of Persia and Syria.

Composition—resin 29, gum 8, 5 extract.

OPOPANAX.

From Turkey and the East Indies,|| from the root of an umbelliferous plant, the *Pastinaca Opopanax*.

Composition—resin 42, gum 33.40, farina 4.20, &c.

* Writers are not agreed as to the origin of this substance.

† Accounted corroborant, and used in disorders of the head, breast and stomach; and in plaisters, unguents and fumigations.

‡ A single dram of the fresh juice smells more than 100 lbs. of the dried extract. The Persians hire ships on purpose for its transportation, as it infects every thing; the odor depends on an essential oil, which rises in distillation both with water and spirit; it is administered in nervous and hysteric affections, &c.; a tincture of it is kept in the shops.

§ A variety of gum.

|| And countries around the Levant.

GAMBOGE.*

From a middling sized tree of Ceylon, Siam and Cochin China, the *Stalagmitis cambogioides*; also from the *Gambogia gutta*.

In small yellow tears; shining conchoidal fracture.

In the blaze of a candle melts, and scintillates.

Alcoholic solution is of a clear gold color.

Acids precipitate it yellow.

Composition.—Resin 80; gum 20.

Used as a water color, but does not stand.†

A very energetic cathartic and emetic.

MYRRH.

Grows in Abyssinia and Arabia; the tree not distinctly known.‡

Composition.—Resin§ 23, gum 77.

SAGAPENUM.

Supposed to be from the *Ferula persica*; very much resembles asafoetida, but weaker in sensible properties.

EUPHORBIVM.

From the milky juice of a large shrub, the *Euphorbia officinalis*.

Taste biting, if held some time in the mouth, producing inflammation, and the powder affects the head violently.||

Composition.—About equal parts of gum and resin.

ALOES.

From the leaves of the aloe.¶

An intimate combination of gum and resin, so perfectly blended, that water and spirit, separately applied, dissolve the greater part of both.

Appendix.

GUIACUM.

A resinous substance, with some peculiar properties.**

* Brought from Cambaja, Cambodja or Gambogia, in the East Indies; thence the name of Cambadium, Cambogium or Gambogium.

† The tincture enters into the lacquer for brass; used also to stain white woods in imitation of box; and to color marble yellow.

‡ Brought from Alexandria. Bruce says it belongs to the genus Mimosa.

§ A cosmetic called oil of myrrh was formed by myrrh and white of egg.

|| Unfit for internal use, but employed in the veterinary art as an epispastic.

¶ There are three sorts of aloes known, *socotrina*, *hepatica*, and *caballina*; these being merely varieties, are here placed in the order of their medical excellence.

** Phil. Trans. 1806. Brande.

Obtained from the *Lignum vitæ*, by heating the bored wood, and the resin flows out through the longitudinal canals.

Has a fragrant smell, when pounded or heated; when swallowed burns in the throat.

Alcohol dissolves it with facility; solution deep brown: becomes milky by water from the separation of the resin.*

Sulphuric acid gives a pale green precipitate. Nitrous ether, with water a fine blue.†

Solution of chlorine, the same; the blue is permanent when dried.

Nitric acid diluted with $\frac{1}{2}$ water gives after some hours a green color, and with more water a green precipitate; ultimately a blue and a brown. One hundred grains of guiacum yield about 9 to water and 95 to alcohol.

SEC. III.—FECULA, FARINA OR STARCH.

(a.) An important proximate principle.

(b.) *Obtained simply by breaking down the texture of the vegetable, and washing it with cold water*, when an incoherent white powder subsides.

(c.) Obtained from all the farinaceous grains and roots; the preparation of starch is a good example.

STARCH.—PROCESS.‡

(a.) *Wheat coarsely bruised or not, is placed in clean water till it softens and swells, and gives out a milky fluid; the grains are pressed or beaten in a hempen bag, while cold water is poured on; the saccharine matter in the grain forms alcohol, and from this, vinegar is generated, which dissolves the gluten, phosphate of lime, and other impurities, and thus whitens the fecula; this is repeatedly washed with cold water, is strained on linen cloth, and laid in a box full of holes; it is then cut into pieces and dried on new bricks and lastly in a stove.§*

(b.) *The fecula can be obtained in a simpler way, by the continued washing, in a small stream of cold water, of a stiff paste of wheat flour, or what I find preferable, the dough after it has partially or completely fermented to make bread; the fecula is carried away in the form of a white powder, and the gluten remains in the hand.*

* Which often presents a curious tremulous appearance as it precipitates and collects into a mass, easily separable from the fluid.

† This change to blue seems characteristic of guiacum, and has been employed to detect its adulterations.

‡ For a good account of these processes see Laugier's *Cours de Chimie*, Vol. III.

§ See Murray's *Chem.* Vol. IV, p. 126, and Atkins' *Dict.* article *Starch*, and *Phil. Mag.* Vol. XXIX.

II. PROPERTIES.

(a.) A fine white powder, soft, insipid, inodorous; in a strong light, and especially with a lens, appearing like brilliant grains; when pressed between the fingers "it breaks with a slight snap and a peculiar short feel."

(b.) Starch* is commonly in prisms like basalt.

(c.) Insoluble in cold water as is evident from the mode in which it is prepared.

(d.) Soluble in hot water, forming a gelatinous fluid or emulsion; thickens by long boiling and unites with boiling water in any proportion.

(e.) If cold water, in which it is diffused, is then heated to 160° or 180°, it is dissolved, and the jelly, when dried, is still soluble in cold as well as hot water.

(f.) Starch, like mucilage, is soluble in hot water; but differs from it in being insoluble in cold water.

(g.) The properties of starch are modified by heat so that it becomes soluble in cold water; this takes place if it is heated a little above 212°, when it turns brown and smells like baked bread, or simply by the action of boiling water in the common mode of making starch paste;† in both cases it is soluble in cold water, and gives the blue color with iodine.

(h.) These properties are augmented by a still higher heat, or by long boiling, and to this modified starch the name of amidine‡ has been given.§

(i.) By torrefaction, starch passes very nearly to the condition of gum, and in that state it is used in the arts in calico printing; it differs however in several particulars both from gum and starch.

(j.) Starch is insoluble in alcohol or ether.

(k.) Acids act on it much as on gum.

(l.) Sulphuric acid slowly dissolves it and evolves much charcoal; the starch dissolved by the diluted acid, may be again precipitated by alcohol.

(m.) Starch is converted into sugar by the modified action of sulphuric acid and of some other acids.|| Sulphuric acid diluted

* The grains are small round and transparent like mother of pearl; they are covered with a smooth envelope insoluble in cold acids, they receive color from iodine, and contain a soluble substance, which, after being heated, is not colored by iodine and resembles a gum; for many curious observations, see Ann. de Ch. et de Ph. Vol. XXXI, XXXIII, and XL.

† By freezing, starch paste is also much altered.

‡ Amyline of Saussure.

§ Ann. de Ch. et de Ph. Vol. XL, p. 193.

|| The details are too full to be quoted in this work. See Thénard, 5th edit. Vol. IV, p. 27.—Ann. de Ch. et de Ph. Vol. XI, p. 387.

with 12* parts of water is boiled with $\frac{1}{4}$ of starch for several hours (36 in the earliest experiment) when it is converted into a kind of sugar which may be crystallized, and will, by fermentation, form alcohol.†

No gas is evolved, the acid is not decomposed, and no change has been ascertained except the addition of more oxygen and hydrogen in the proportions to form water.‡

(n.) *Dilute nitric acid slowly dissolves a part of the starch*, and becomes green.

(o.) *Strong nitric acid acts with energy*, and emits nitrous gas; with heat, both oxalic and malic acids are formed.

(p.) *Strong muriatic acid dissolves it slowly* without effervescence; the solution is colorless if the starch is not more than $\frac{1}{16}$, otherwise it is brown, the smell of the acid is destroyed and that of corn mills succeeds.

(q.) *Alkalies, in aqueous solution, dissolve it without heat*; it is again precipitated by acids.

(r.) Alcohol, acetate of lead, muriate of tin, and infusion of galls, precipitate the aqueous solution of starch.

Composition, according to Thénard and Gay-Lussac is

Oxygen,	-	-	-	-	-	-	-	49.68
Carbon,	-	-	-	-	-	-	-	43.55
Hydrogen,	-	-	-	-	-	-	-	6.77

100.00

The analysis of Berzelius gives a similar result. The composition of starch is so analogous to that of sugar, that it is not surprising it should be converted into that principle by germination, and by other agencies.

Proust has given the name hordein,‡ to a principle, probably a variety of starch, from which he conceives the sugar to be derived in malting, and it is observed that frost produces a similar change upon the potatoe, the apple and the parsnip.

* 100 potatoe starch, 2 sulphuric acid, and 400 water, by boiling, produce raisin sugar; the acid is withdrawn by chalk, and the filtered fluid is evaporated.—G. L.

† If the temperature exceeds 212° F. less acid is required, and the change is effected in a shorter time; 1 to 2 parts of acid, to 100 potatoe starch, in 2 or 3 hours gives crystallizable sugar.—*Eng. Quart. Jour. No. XIV.*

‡ Saussure stated that the sugar is more in weight than the starch, but this has been since denied.

‡ Barley,	contains in	100 parts.	Malt in 100 parts contains
Resin,	-	1	1
Gum,	-	4	15
Sugar,	-	5	15
Gluten,	-	3	1
Starch,	-	32	56
Hordein,	-	55	12

(Proust quoted by Henry;) in malting, gum, sugar and starch are increased and gluten and hordein diminished.

Iodine is the best test for starch;* its solution produces with iodine blue,† purple and other colors; it is said that the compound is white when the proportion of iodine is very small, but black if it is large.

III. KINDS AND SOURCES.

(a.) *Fecula is contained in all nutritive seeds grains and roots*; most plants contain a portion, mixed or combined with vegetable extract, sugar, gluten, albumen, mucilage or oil.‡

(b.) *Among roots, it is found especially in the tuberous and bulbous*; in the pith of trees and plants; sometimes, as in the lichens, diffused through the whole.

(c.) *Fully formed, only in certain stages of vegetation*; in the nutritive grains, perfect only at maturity; before that, like a saccharine mucilage, which appears to change into fecula.

POTATOE STARCH.

(a.) *The potatoe affords much very pure fecula*; the mealy appearance of the boiled potatoe when broken, is owing to a congeries of fine soft grains of fecula.

(b.) *Extraction*: the root is *peeled and grated*, the pulp is placed on a sieve and *washed* with cold water; and the fecula is repeatedly washed and then dried.

(c.) *Forms from 15 to 17 pr. ct.* the remaining parts being water with 8 or 9 fibrous matter, and 5 or 6 mucilage.

(d.) *A good substitute for wheat starch*, it is much heavier and more economical; a smaller portion forms a thick paste with water.

SAGO.

(a.) *Extracted from the pith of several species of palms* in the Moluccas, Philippine and other East India isles.

(b.) *Process*.—The tree being cut into pieces of 5 or 6 feet long, it is hollowed so as to uncover the pith, which is agitated with cold water; the fecula, being thus separated from the fibrous part, is passed through a sieve; after it has settled, the water is poured off, and when partially dry, it is passed through perforated copper plates, and thus granulated.

(c.) *It becomes gray by drying*; very nutritious and much used in sickness; the natives form the medulla of the palm into cakes which they eat.

* See p. 74 of this Vol.

† Applied in the arts to discover whether goods have been finished with starch; if so, a drop of a solution of iodine produces a blue color.

‡ Atkins.

SALOP.

(a.) Said to be derived from the prepared roots of different species of *Orchis* as *Morio*, *mascula*, *bifolia*, *pyramidalis*.

(b.) *Process*.—The bulbous roots being deprived of their cuticle and baked for 10 or 12 minutes, become semi-transparent and are then fully dried in a moderate heat.* This fecula is used for food.

CASSAVA.

(a.) Prepared from the roots of the *Jatropha manihot*, the manioc.

(b.) *Process*.—The roots being peeled and pressed in a bag made of rushes, a juice exudes with which the natives poison their arrows.

(c.) The fecula, after suitable washing, is innocent.

(d.) While still in the bag it is dried in smoke, and then passed through a sieve.

(e.) Of this substance the cassava bread is made; cassava is said to have a calming effect. Tapioca is only the finest deposit of the cassava.

ARROW ROOT POWDER is the product of the *Maranta arundinacea* or *Maranta indica*. The roots are washed clean, beaten to a pulp, worked by hand, the fibrous part rejected, the milky liquor strained, and the sediment washed and dried in the sun.—H.

Composition.

SOWANS.†—Prepared in Scotland from the flour of oats by a process similar to that used for common starch.

THE LICHENS contain much fecula; the Lichen *Icelandicus* is very nutritious; when pulverized, it affords fecula nearly pure, it gives however a brown and not a blue with iodine.‡

THE ROOT OF ELECAMPANE§ (*Inula Helenium*) affords a substance which has been called *inulin* but appears to be only a variety of fecula. It does not strike a blue with iodine, and is more soluble in both hot and cold water than starch.

It is deposited from a decoction of the root after it has stood some hours:

Remark.||—There is no vegetable matter so well adapted to the support of life as fecula, and it forms the principal part of all the seeds and roots which are used as articles of food by man. Rice

* Thomson.

† Hogs swallow greedily and thrive on the starch-maker's sour water, and the liquor of the sowans.—Thomson.

‡ It has a disagreeable taste which is removed by potash water.

§ Also the *Colchicum autumnale*, the *Anthemis Pyrethrum*, and the *Angelica Archangelica*.

|| For much and various information respecting the feculas and the connected subjects, see Ann. de Ch. et de Ph. Vols. V, XXXI, XXXIII, XXXV and XL. Ann. of Phil. Vol. V, p. 272, XII, p. 337. Phil. Mag. Vol. XLIX.

and the potatoe, which, without other aid, are sufficient to sustain life, scarcely contain any thing nutritious besides fecula.

In the state of gelatinous solution, fecula is used for pasting and stiffening linen and other kinds of cloth; and it enters into the composition of some pigments.—*Murray*.

SEC. IV.—GLUTEN.

A vegetable principle analogous to animal matter, particularly to gelatine, whence its name of gluten.

I. PREPARATION.

(a.) The usual mode is to let a slender stream of cold water fall upon a tough ductile paste of wheat flour, made with little water and much kneading,* and sustained in the hand or in a hempen bag.

(b.) I find that a better method is to take a piece of dough, one or two days old, work it carefully in the hands over a bowl of water, moistening the mass by dipping it slightly and frequently; this affords gluten in a very good state, and much better than with a stream of water; the farina is washed out and the gluten becomes more tenacious the more it is washed and worked.†

II. PHYSICAL PROPERTIES.

(a.) *A soft, tenacious, viscous and elastic substance*; it can be stretched,‡ and pulled, and moulded into any form; adhesive, sticking to the fingers.§

(b.) *Texture fibrous, silky and pearly, nearly tasteless, color dirty gray, smell faint and peculiar*; when dried it is brittle; semi-transparent, and resembles glue; in thin pieces looks like animal membrane; it breaks with a vitreous fracture.

* Taking care not to drench the flour at first with too much water.

† The quantity of gluten obtained from wheat flour is about 1-12 of its weight or, if the water be taken into account, from 1-3 to 1-5; the farina lies sheathed in the fibres of the gluten and is mechanically washed out. It cannot be easily extracted from the other nutritive grains, although it is contained in them or most of them; if kernels of wheat are gently pressed between the teeth and tongue, the gluten is soon perceived by its tenacity; there are traces of it in maize.

‡ It may be stretched to twenty times its original length. Its peculiar character is pleasingly exhibited by holding it in both hands and then separating them gradually to the greatest distance; the gluten will stretch out into a fibrous ductile rope, which may be wound over the hands by passing them quickly around each other, and then it may be extended again, and so on. If a person stand as nigh to the ceiling of the room as possible, and hold the gluten aloft, it will run down to the floor in ropes and threads, although it should be twenty feet, and may be received in any convenient vessel, and then it can be worked over again, and it becomes more plastic by being wrought in the hands; after the repose of a night it is never fit for exhibition, until it has been worked over again.

§ And for this reason used to join broken crockery.

(c.) *Its elasticity and ductility are owing to water, which, when fresh, it imbibes and retains with considerable force; it does not lose its tenacity in the mouth.*

III. CHEMICAL PROPERTIES.

(a.) *In a warm dry atmosphere it loses water and becomes hard; in a moist one it remains soft and putrefies with an animal odor; ammonia is formed.**

(b.) *Insoluble, or but slightly soluble in water,† but if boiled in it, loses its adhesiveness, elasticity and tenacity.*

(c.) *When long immersed in water it putrefies; carbonic acid, ammonia, and hydrogen are evolved, and acetic acid is formed.‡*

(d.) *Gluten is insoluble in cold alcohol and in ether, it even precipitates the little which water has taken up.*

(e.) *The gluten mentioned in c, by trituration with alcohol, forms a thick syrup,§ which is a transparent firm elastic varnish, a cement for porcelain,|| and a basis for paints.*

(f.) *Acids act variously on gluten.*

(g.) *Strong acetic acid forms a muddy solution, and the gluten is precipitated by alkalies; it forms a varnish or cement.*

(h.) *By strong sulphuric acid it is carbonized, acetic acid and ammonia are produced and carburetted hydrogen gas is evolved.*

(i.) *Hot nitric acid evolves nitrogen and forms oxalic and malic acids.*

(j.) *Hot muriatic acid dissolves it, like the acetic.*

(k.) *It is softened by chlorine, and changed into a yellowish flocculent matter.¶*

(l.) *The acetates of lead and nitrate of mercury give precipitates; the remaining liquid assumes a pink color.*

(m.) *Infusion of galls gives a copious precipitate.*

(n.) *Hot alkalies dissolve gluten, and the acids precipitate it.*

(o.) *It is affected by heat like animal bodies; when suddenly dried, it swells at first; and if heated in the air it shrinks and coils like a*

* According to Proust, the products of sour milk called caseic acid and caseous oxide are also formed, (Ann. de Ch. et de Ph. Vol. X. p. 38.) If the fecula has not all been washed out, it produces vinegar which converts the gluten into a caseous matter, and by the addition of salt, it may be preserved in that state. When thoroughly dry and preserved in that condition it undergoes no change.

† Water, in a long time, takes up enough to precipitate the acetate of lead and muriate of tin.—Bostock.

‡ Something is dissolved in the water which separates in glutinous flocculi when it is heated. Fourcroy thought from this that gluten was soluble in water, but it is more probable that this matter is some modification of gluten.

§ More spirit separates a part of the gluten, but a part remains dissolved; this is precipitated by water.

|| It is mixed with lime, and bits of linen dipped in it, adhere firmly to other bodies.

¶ Chlorine precipitates it from solution, and thus becomes a test of its presence.

soft animal substance and then melts and burns, with the odor of burning feathers or horn.

(p.) *When distilled, it emits a fetid odor; affords carbonate of ammonia,* in crystals and in solution; also viscid oil, inflammable gas and charcoal, difficult to ignite.*

(q.) *Composition.*†—*Gluten*, obviously, contains carbon, hydrogen and nitrogen, and a little phosphate of lime;‡ it *approximates to animal matter*. Ether does not act on gluten.

(r.) *Gluten appears to promote fermentation; yeast, which is the dried froth of fermenting beer and of all fermenting fruits, has been supposed to act in consequence of the gluten which it contains, for, by distillation, it affords the same products as gluten; water, in which gluten, away from air, has been macerated for some time, converts sugar into excellent vinegar; there is no effervescence. Neither the composition of yeast nor its mode of action in producing fermentation is known.*

IV. VARIETIES.

(a.) Rouelle found gluten in the leaves of all the vegetables which he examined, and Proust has confirmed this observation.

(b.) Gluten exists in acorns, chesnuts, horse chesnuts, rice, barley, rye, peas and beans, and in apples and quinces; also in the leaves of cabbage, sedums, cress, hemlock, borage, saffron; in the berries of the elder and grape; in the petals of the rose; it occurs also in several roots; none has been found in the potatoe.

(c.) There is also in the green juice which is obtained, by pressure, from succulent plants, a fecula which subsides, or is removed by the filter, and the liquor holds in solution a matter which is of the nature of gluten, since it ferments with an animal odor and yields ammoniacal products.

Remarks.—*Gluten is a very important vegetable principle.* It is admirably adapted to animal nutrition; hence, the superiority of wheat to other grains, and also on account of the viscosity which it

* It does not afford acids, like vegetable matter, the carbonic acid excepted.

† *Supposed new principles in gluten.*—M. Taddel, of Italy, has announced two bodies, gliadine (γλια, gluten,) and zimome, (ζυμη, a ferment,) but Berzelius has proved (Ann. de Chim. et de Phys. Vol. XXXVII, p. 215,) that the gliadine is a modified gluten, similar to that extracted from rye, barley and peas, and the zimome is albumen. The peculiar gluten is soluble in boiling alcohol, from which it is obtained by dilution and distillation; it remains in the retort; the albumen rests undissolved in the alcohol. Guaiacum is a test to discover when flour contains the proper proportion of albumen or gluten; it is kneaded with the flour, and if it is good it produces a beautiful blue color, which is intense if the albumen (the so called zimome,) has been obtained and used pure. It does not take place with starch, nor if the air is excluded. I do not introduce these new names into the text, as they may serve only to distract the learner.

‡ The vapor which gluten emits, while fermenting, blackens silver, and therefore it is inferred that it contains sulphur; in this, and in similar cases, it is doubtless derived from the decomposition of the soluble sulphates, accidentally present.

imparts to the dough; during the fermentation this entangles the carbonic acid gas,* and thus causes a well baked wheat loaf to be light, to a degree not found in any other flour. In oats, barley, rye and rice there is little or no gluten, as is the case with the nutritive roots also, and hence, although they may form a paste or a pudding, they cannot, alone, form bread. Potatoes are frequently added to wheat flour, and a good bread is the result; the potatoe contains farina, and the flour gluten, which favors the rising. When bread is over raised, acetic acid is generated, but it is easily neutralized by a solution of pearlash, or by some other alkaline substance, and the carbonic acid evolved renders the bread still lighter; if the sourness is discovered before the baking, it can always be in this manner removed.

The wheat of warm climates contains in general the most gluten, and that of this country more than that of England.† Sir H. Davy has given the following facts.

	Fecula.	Gluten.
100 parts best wheat sown in Autumn gave	77	19
100 " " Spring,	70	24
100 " Barbary,	74	23
100 " Sicilian,	75	21
100 " Norfolk barley,	79	6
100 " Suffolk rye,	61	5

Mr. Henry of Paris found only $10\frac{1}{2}$ per cent. of gluten in the wheat of France for 1827 and 28.‡

Sir H. Davy remarks that the predominance of gluten in the wheat of the south of Europe, fits it peculiarly for making macaroni and other glutinous preparations. It is from the admirable blending of farina and gluten in wheat flour, that it is so well adapted to the formation of bread; it contains also albumen, sugar and mucilage.

It is curious, that considerable alcohol is produced during the pary fermentation; but we may presume that it is expelled by the baking. The gases exhaled from fermenting or recently baked bread are noxious, and asphyxia has been produced by them.

SEC. V.—SUGAR.

A very important product extensively diffused, and, in the most general sense, called the saccharine principle.§

Sugar, besides the sweet taste, undergoes the vinous fermentation by the aid of yeast. There are three principal kinds.

* Hydrogen gas is also found in leaven. † Agric. Chem. Am. Edit. 1815, p. 126.

‡ Ann de Ch. et de Ph. Vol. XL, p. 223.

§ Dr. Prout, (Phil. Trans. 1827,) has extended this term so as to include all the alimentary vegetable substances, because they are alike in containing oxygen and hydrogen in the proportions to form water; this is, I conceive, an unfortunate departure from the established use of language, and tends to produce unnecessary confusion.

1. That from the cane, beet and maple, forms distinct crystals.
2. When obtained from the grape, from honey, from starch and ligneous fibre, and from the efflorescence on dried fruits, it does not crystallize but only grains.
3. If from mushrooms, it crystallizes promptly from the alcoholic solution, in delicate needles.

I. PHYSICAL AND CHEMICAL PROPERTIES.

(a.) *When pure, sugar is a firm, white substance, inodorous, and perfectly sweet,** very permanent, but becoming moist in a damp air; sp. gr. of loaf sugar is 1.6 to 1.65.†

(b.) *It is usually seen in brilliant grains, more or less crystalline,‡ and in sugar candy, distinctly crystallized; the crystal is a prism of 4 or 6 sides, beveled at each extremity, or acuminate by three planes; most usually an oblique four sided prism with dihedral summits.§* The crystals are translucent; sometimes almost transparent.

(c.) *To form the crystals, the syrup is clarified and concentrated, but not to a degree proper to form loaf sugar; the syrup is poured into boxes containing light frames with thread stretched from side to side; the boxes are placed, for some time, in the drying stove, and on withdrawing the frames, the threads are found beautifully studded with crystals whose fracture is vitreous.*

(d.) *Sugar is phosphorescent in the dark by the friction or percussion of firm masses.*

(e.) *Soluble in 1 or 2 parts of water at 50°; in less above that degree, and indefinitely at 212°.*

(f.) *The aqueous solution of sugar is called syrup; it is thick and viscid; if pure it can be kept any length of time, but if mixed with mucilage, farina, &c. it runs into the vinous fermentation.*

(g.) *Soluble in alcohol; in 4 parts if boiling, and, on cooling, elegant crystals are deposited; weak alcohol dissolves more than strong, the highest scarcely dissolves any.*

The strong acids decompose sugar.

(h.) *The sulphuric evolves charcoal, forms water and probably acetic acid;¶ if aided by heat, sulphurous acid gas is evolved.*

* Sweet—like the terms acid, alkaline, &c. referring to sensation, scarcely admits of definition except negatively; we can say that it is contrasted with sour; that it is unlike alkaline, metallic, astringent, &c. &c.; we may class it however among the tastes that are most agreeable.

† 1.40 Hassenfratz; 1.56 Thomson.

‡ It often retains a portion of oily, mucilaginous, or extractive matter.

§ *Sugar candy* is formed by slow crystallization, while in loaf and lump sugar the regularity of this process is purposely disturbed by agitation; the presence of vegetable acid retards the crystallization.

¶ The brown crystals are as perfect in their form as the white, although they are more clammy, and apt to become moist, while the white candy remains dry.

¶ Or other vegetable acid or acids.

(i.) *The nitric acid is decomposed by sugar and also decomposes it in turn; gases are copiously evolved and oxalic and malic acids formed, but never the mucous acid.*

(j.) *Aqueous solution of chlorine dissolves powdered sugar, and forms malic and muriatic acids.*

(k.) *Solutions of fixed alkalies, combine with sugar; the alkaline properties are little altered, while the sweet taste is nearly destroyed; but on neutralizing the alkali by sulphuric acid, and precipitating the sulphate by alcohol, the sweetness is completely restored, as the alcohol now suspends the sugar in solution.*

(l.) *Alkaline earths act on sugar as alkalies do; after lime is boiled with sugar, it has a bitter astringent taste mixed with sweet; lime, baryta and strontia are rendered much more soluble, and the sulphuric acid separates them, and restores the sweet taste.*

(m.) *An aqueous solution of sugar, boiled with muriate of gold or with the nitrate of mercury or silver, or with sulphate or acetate of copper decomposes them, and either evolves the metal, or causes the oxide to lose oxygen: it forms with oxide of lead, a compound, at first soluble and then a precipitate which is insoluble;* it is composed*

of sugar,	-	-	-	-	41.74
protoxide of lead,	-	-	-	-	58.26

100.

Sub acetate of lead does not precipitate sugar from its solution, but it does precipitate other vegetable principles; it affords therefore a good means of discrimination.

(n.) *Sugar melts at a heat considerably above that of boiling water and forms a blood-red viscid fluid; it takes fire by a flame, and burns with a red light, and a suffocating odor.*

(o.) *By destructive distillation, it affords acetic and pyro-mucous acid and empyreumatic oil, carburetted hydrogen and carbonic acid gases, and charcoal remain; 1 oz. of sugar, decomposed by heat, gave acid with a little empyreumatic oil, 4 dr. 30 gr.; charcoal, 2 dr.; carburetted hydrogen gas 119 oz. measures; carbonic acid, 41 oz. measures.*

II. COMPOSITION.

(a.) *Sugar appears to be a very pure oxide of carbon and hydrogen; affording neither nitrogen, ammonia nor lime.*

* Dr. Prout obtained it in beautiful crystals.

Results of various analyses.

	Lavoisier.	Gay-Lussac.	Berzelius.	Prout.	Ure.	Crum.
Carbon,	28	42.47	44.200	42.85	41.8	43.38
Oxygen,	64	50.63	49.015	50.80	51.7	50.33
Hydrogen,	8	6.90	6.785	6.35	6.5	6.29
	100	100.	100.	100.	100.	100.

(b.) *The oxygen and hydrogen are in the proportions to form water.*—Dr. Prout regards sugar as a compound of carbon and water, and he takes the same view of the other compounds that have a similar constitution: but as we know not of any case in which a mere combination with water produces such important results; as we know not that carbon will combine with water at all, and as the supposition of a ternary compound of oxygen, carbon, and hydrogen corresponds much better with the general analogy of vegetable constitution, the latter view seems more philosophical and therefore preferable.

Remark.

Phosphuret of lime, the alkaline hydro-sulphurets and sulphurets and other substances, which attract oxygen, bring sugar towards the condition of mucilage.

Dr. Prout, in his elaborate memoir,† has shewn that the sugar of commerce varies in its constitution. Besides sugar candy, and several varieties of the cane sugars, he examined that of the beet, maple, honey, starch, &c.; the highest proportion of carbon found by him was 42.85, and the lowest 36, being that contained in raisin sugar; the highest amount of the elements of water, (taking them in combination) was 64 and the lowest 57.5; the sugar of the cane and of the beet and maple, contains more carbon than any other. The results of analysis, as yet, scarcely afford a sure conclusion as to the equivalents of the elements of sugar; but, taking the purest sugar-candy as the standard, we have a near approximation to the following numbers,

					per. cent.
Carbon,	6 equiv.	-	-	-	36
Oxygen,	5	-	-	-	40
Hydrogen,	5	-	-	-	5
					6.18

the equiv. of sugar 81 100.

and a similar conclusion is obtained from the compound of sugar with oxide of lead. Sugar dried at 212° F. is a hydrate with 1 equiv. sugar + 1 water.—H.

† Phil. Trans. 1827.

III. HISTORY.

Manufactured in China and India, before it was known in Europe; Alexander of Macedon is supposed to have brought the knowledge of it from the East; and for a long time after, it was used only as a medicine. During the crusades, the Venetians imported it in larger quantities, but it did not become extensively an article of food, until after the West Indies were peopled by Europeans; it was formerly raised in the Southern parts of Europe.—*Thomson.*

IV. SOURCES, VARIETIES* AND MODES OF PREPARATION.

1. SUGAR OF THE CANE.†

(a.) At a particular season, *the juice of the sugar cane, is little else than syrup*; to obtain it, *the cane is cut short, tied in bundles and ground in a mill, consisting of three upright rollers or cylinders of iron thirty or forty inches long and twenty or twenty five in diameter*; the moving power is applied to the middle cylinder, which, by means of cogs, turns the others.

(b.) *The cane is made to pass twice between these cylinders, and is squeezed dry*; the macerated rind is called cane trash; *the juice is received below in a leaden bed, and thence conveyed into the clarifying vessels.*

(c.) This must be done immediately, for, if the juice stands, in considerable quantities, only twenty minutes, it begins to ferment.

(d.) *Beneath the boilers or clarifiers, which are large copper pans, a fire is kindled, by means of the cane trash*; lime, in the proportion of from half a pint to a pint to every 100 gallons of liquor, *is added to neutralize vegetable acids*, particularly the oxalic, and to remove extractive and other principles, as they would prevent the sugar from crystallizing.‡

(e.) *A thick scum rises as the liquor heats, and that it may not break, the temperature is maintained below boiling*; after about forty minutes, *the liquor is allowed to stand one hour, to become clear, and is then drawn off* by means of a syphon or cock.

(f.) *It is now passed into the grand evaporating basin or copper, where it is made to boil as quickly as possible, and the scum is removed as it forms.*

(g.) *This operation is twice more repeated by running it, in succession, into two other coppers—into the smaller one last, with the addition of lime water, if the fluid continues foul.*

* For full accounts of the manufacture of sugar, see Edwards' History of the West Indies, and Aikins', and Nicholson's and Ure's Dict.

† The cane is richer in sugar than any other vegetable.

‡ If too much lime is used, it adheres to the raw sugar and makes it clammy; (Ann. de Chim. et de Phys. Vol. X, p. 219;) alum also is added.

(h.) *The last evaporating vessel is called a teache, and, in this, the evaporation is carried so far that the liquor becomes thick and tenacious, and the sugar grains or crystallizes as it grows cold; to effect this first imperfect crystallization, the liquor is run into shallow wooden vessels, called coolers, where it forms a crude mass of imperfect crystals mixed with the treacle or molasses.*

(i.) *To separate this, the sugar is drained in hogsheads, standing on frame work and perforated in the lower head with a number of holes, partially obstructed by stalks of the long plantain leaf, which, being porous, permits the molasses to filter through.*

(j.) *In about three weeks the sugar is tolerably dry and fair, and is then fit for exportation, as raw or muscovado sugar, which is sugar still brown from admixture with a portion of molasses; a gallon of juice affords a pound of raw sugar. The molasses sometimes deposits large and distinct crystals in the casks, and a similar fact is observed in family use; molasses is a solution of real sugar, with various saline, acid, mucilaginous and other vegetable principles.*

2. CLAYING OF SUGAR.

(a.) In general, sugar undergoes no farther refining in the West Indies;

(b.) But in the French islands, they take the sugar from the cooler before it is drained of the molasses, and pour it into conical earthen pots, perforated at the apex, which is placed lowest, resting in another pot.

(c.) This hole is stopped with a plug, till the sugar has congealed, when it is withdrawn and the molasses allowed to drop out.

(d.) To purify it still more, clay, mixed with water, to the consistence of cream, is poured on the sugar, and the water from the clay, oozing through, washes out the remaining molasses.

(e.) *The claying is repeated two or three times, and for economy they use a solution of syrup instead of water; the pots remain twenty days in this situation, when the sugar is taken out, dried in the sun, for some hours, and then, for three weeks, in a room heated by a stove.**

3. REFINING OF SUGAR.

(a.) The claying of sugar is a mode of refining it, but there is a more perfect process which frequently embraces this also.

* It is said that the first hint for claying sugars was derived from accident. "A hen, having her feet dirty, going over a pot of sugar, it was found under her feet to be whiter than elsewhere."—Sloane, in Nicholson's Dictionary.

SALOP.

(a.) Said to be derived from the prepared roots of different species of *Orchis* as *Morio*, *mascula*, *bifolia*, *pyramidalis*.

(b.) *Process*.—The bulbous roots being deprived of their cuticle and baked for 10 or 12 minutes, become semi-transparent and are then fully dried in a moderate heat.* This *secula* is used for food.

CASSAVA.

(a.) Prepared from the roots of the *Jatropha manihot*, the manioc.

(b.) *Process*.—The roots being peeled and pressed in a bag made of rushes, a juice exudes with which the natives poison their arrows.

(c.) The *secula*, after suitable washing, is innocent.

(d.) While still in the bag it is dried in smoke, and then passed through a sieve.

(e.) Of this substance the cassava bread is made; cassava is said to have a calming effect. Tapioca is only the finest deposit of the cassava.

ARROW ROOT POWDER is the product of the *Maranta arundinacea* or *Maranta indica*. The roots are washed clean, beaten to a pulp, worked by hand, the fibrous part rejected, the milky liquor strained, and the sediment washed and dried in the sun.—H.

Composition.

SOWANS.†—Prepared in Scotland from the flour of oats by a process similar to that used for common starch.

THE LICHENS contain much *secula*; the Lichen *Icelandicus* is very nutritious; when pulverized, it affords *secula* nearly pure, it gives however a brown and not a blue with iodine.‡

THE ROOT OF ELECAMpane§ (*Inula Helenium*) affords a substance which has been called *inulin* but appears to be only a variety of *secula*. It does not strike a blue with iodine, and is more soluble in both hot and cold water than starch.

It is deposited from a decoction of the root after it has stood some hours:

Remark.||—There is no vegetable matter so well adapted to the support of life as *secula*, and it forms the principal part of all the seeds and roots which are used as articles of food by man. Rice

* Thomson.

† Hogs swallow greedily and thrive on the starch-maker's sour water, and the liquor of the sowans.—Thomson.

‡ It has a disagreeable taste which is removed by potash water.

§ Also the *Colchicum autumnale*, the *Anthemis Pyrethrum*, and the *Angelica Archangelica*.

|| For much and various information respecting the *seculas* and the connected subjects, see *Ann. de Ch. et de Ph.* Vols. V, XXXI, XXXIII, XXXV and XL. *Ann. of Phil.* Vol. V, p. 272, XII, p. 337. *Phil. Mag.* Vol. XLIX.

and the potatoe, which, without other aid, are sufficient to sustain life, scarcely contain any thing nutritious besides secula.

In the state of gelatinous solution, secula is used for pasting and stiffening linen and other kinds of cloth; and it enters into the composition of some pigments.—*Murray.*

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A vegetable principle analogous to animal matter, particularly to gelatine, whence its name of gluten.

I. PREPARATION.

(a.) The usual mode is to let a slender stream of cold water fall upon a tough ductile paste of wheat flour, made with little water and much kneading,* and sustained in the hand or in a hempen bag.

(b.) I find that a better method is to take a piece of dough, one or two days old, work it carefully in the hands over a bowl of water, moistening the mass by dipping it slightly and frequently; this affords gluten in a very good state, and much better than with a stream of water; the farina is washed out and the gluten becomes more tenacious the more it is washed and worked.†

II. PHYSICAL PROPERTIES.

(a.) *A soft, tenacious, viscous and elastic substance*; it can be stretched,‡ and pulled, and moulded into any form; adhesive, sticking to the fingers.§

(b.) *Texture fibrous, silky and pearly, nearly tasteless, color dirty gray, smell faint and peculiar*; when dried it is brittle; semi-transparent, and resembles glue; in thin pieces looks like animal membrane; it breaks with a vitreous fracture.

* Taking care not to drench the flour at first with too much water.

† The quantity of gluten obtained from wheat flour is about 1-12 of its weight or, if the water be taken into account, from 1-3 to 1-5; the farina lies sheathed in the fibres of the gluten and is mechanically washed out. It cannot be easily extracted from the other nutritive grains, although it is contained in them or most of them; if kernels of wheat are gently pressed between the teeth and tongue, the gluten is soon perceived by its tenacity; there are traces of it in maize.

‡ It may be stretched to twenty times its original length. Its peculiar character is pleasingly exhibited by holding it in both hands and then separating them gradually to the greatest distance; the gluten will stretch out into a fibrous ductile rope, which may be wound over the hands by passing them quickly around each other, and then it may be extended again, and so on. If a person stand as nigh to the ceiling of the room as possible, and hold the gluten aloft, it will run down to the floor in ropes and threads, although it should be twenty feet, and may be received in any convenient vessel, and then it can be worked over again, and it becomes more plastic by being wrought in the hands; after the repose of a night it is never fit for exhibition, until it has been worked over again.

§ And for this reason used to join broken crockery.

(c.) *Its elasticity and ductility are owing to water*, which, when fresh, it imbibes and retains with considerable force; it does not lose its tenacity in the mouth.

III. CHEMICAL PROPERTIES.

(a.) *In a warm dry atmosphere it loses water and becomes hard; in a moist one it remains soft and putrefies* with an animal odor; ammonia is formed.*

(b.) *Insoluble, or but slightly soluble in water*,† but if boiled in it, loses its adhesiveness, elasticity and tenacity.

(c.) *When long immersed in water it putrefies*; carbonic acid, ammonia, and hydrogen are evolved, and acetic acid is formed.‡

(d.) *Gluten is insoluble in cold alcohol and in ether*, it even precipitates the little which water has taken up.

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(f.) *Acids act variously on gluten*.

(g.) *Strong acetic acid forms a muddy solution*, and the gluten is precipitated by alkalies; it forms a varnish or cement.

(h.) *By strong sulphuric acid it is carbonized*, acetic acid and ammonia are produced and carburetted hydrogen gas is evolved.

(i.) *Hot nitric acid evolves nitrogen* and forms oxalic and malic acids.

(j.) *Hot muriatic acid dissolves it*, like the acetic.

(k.) *It is softened by chlorine*, and changed into a yellowish flocculent matter.¶

(l.) *The acetates of lead and nitrate of mercury give precipitates*; the remaining liquid assumes a pink color.

(m.) Infusion of galls gives a copious precipitate.

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‡ Something is dissolved in the water which separates in glutinous flocculi when it is heated. Fourcroy thought from this that gluten was soluble in water, but it is more probable that this matter is some modification of gluten.

§ More spirit separates a part of the gluten, but a part remains dissolved; this is precipitated by water.

|| It is mixed with lime, and bits of linen dipped in it, adhere firmly to other bodies.

¶ Chlorine precipitates it from solution, and thus becomes a test of its presence.

soft animal substance and then melts and burns, with the odor of burning feathers or horn.

(p.) *When distilled, it emits a fetid odor*; affords carbonate of ammonia,* in crystals and in solution; also viscid oil, inflammable gas and charcoal, difficult to ignite.

(q.) *Composition.*†—*Gluten*, obviously, contains carbon, hydrogen and nitrogen, and a little phosphate of lime;‡ it *approximates to animal matter*. Ether does not act on gluten.

(r.) *Gluten appears to promote fermentation*; yeast, which is the dried froth of fermenting beer and of all fermenting fruits, has been supposed to act in consequence of the gluten which it contains, for, by distillation, it affords the same products as gluten; water, in which gluten, away from air, has been macerated for some time, converts sugar into excellent vinegar; there is no effervescence. *Neither the composition of yeast nor its mode of action in producing fermentation is known.*

IV. VARIETIES.

(a.) Rouelle found gluten in the leaves of all the vegetables which he examined, and Proust has confirmed this observation.

(b.) Gluten exists in acorns, chesnuts, horse chesnuts, rice, barley, rye, peas and beans, and in apples and quinces; also in the leaves of cabbage, sedums, cress, hemlock, borage, saffron; in the berries of the elder and grape; in the petals of the rose; it occurs also in several roots; none has been found in the potatoe.

(c.) There is also in the green juice which is obtained, by pressure, from succulent plants, a fecula which subsides, or is removed by the filter, and the liquor holds in solution a matter which is of the nature of gluten, since it ferments with an animal odor and yields ammoniacal products.

Remarks.—*Gluten is a very important vegetable principle.* It is admirably adapted to animal nutrition; hence, the superiority of wheat to other grains, and also on account of the viscosity which it

* It does not afford acids, like vegetable matter, the carbonic acid excepted.

† *Supposed new principles in gluten.*—M. Taddei, of Italy, has announced two bodies, gliadine (γλια, gluten,) and zimome, (ζιμη, a ferment,) but Berzelius has proved (Ann. de Chim. et de Phys. Vol. XXXVII, p. 215,) that the gliadine is a modified gluten, similar to that extracted from rye, barley and peas, and the zimome is albumen. The peculiar gluten is soluble in boiling alcohol, from which it is obtained by dilution and distillation; it remains in the retort; the albumen rests undissolved in the alcohol. Guaiacum is a test to discover when flour contains the proper proportion of albumen or gluten; it is kneaded with the flour, and if it is good it produces a beautiful blue color, which is intense if the albumen (the so called zimome,) has been obtained and used pure. It does not take place with starch, nor if the air is excluded. I do not introduce these new names into the text, as they may serve only to distract the learner.

‡ The vapor which gluten emits, while fermenting, blackens silver, and therefore it is inferred that it contains sulphur; in this, and in similar cases, it is doubtless derived from the decomposition of the soluble sulphates, accidentally present.

(g.) *Burns like animal matter, and destructive distillation gives an animal product*, carbonate of ammonia, besides carbonic acid and carburetted hydrogen gases; a light charcoal remains, difficult to burn, and its ashes contain lime and its phosphate.

(h.) *Nitric acid produces much prussic and oxalic acids*, and carbonic acid and nitrogen are evolved.

(i.) *Aqueous solution putrefies*, like animal matter.*

(j.) *This vegetable principle is therefore assimilated to animal albumen*, and this, with gluten, forms a connecting link between the two kingdoms.†

We have already mentioned the substance called zimome, which appears to be albumen; it remains after the action of boiling alcohol upon gluten. Albumen is found also in the juices of milky vegetables; it is contained in the houseleek, in cabbage, and in most of the cruciform plants.

It is found in the washings of starch, which when boiled, deposit a white substance, apparently albumen, coagulated by the heat; it floats as a bulky scum. Albumen exists in the emulsive seeds, as the sweet and bitter almond.

SEC. VII.—JELLY.

Remark.—It is very probable that this is not a distinct proximate principle, but, as it is a frequent vegetable product, it is convenient to give it a place.

Preparation.—The expressed juice of blackberries, currants, raspberries, strawberries, &c. by boiling or repose, especially in the sun, will gelatinize, and the jelly, being washed with cold water, will be nearly pure.‡

PROPERTIES.

(a.) *Colorless*, unless tinged by the fruit.

(b.) *Almost insoluble in cold, but very soluble in hot water*, from which the jelly precipitates again as it cools, but the power of gelatinizing may be destroyed by long boiling, as happens when, there being too little sugar,§ the juice is boiled down to concentrate it; it then approximates to the character of mucilage.

* Carbonic acid caused the liquid juice to fly, when the bottle was opened; caecous matter, the result of decomposition, swam in the liquor; when dry, it was like horn; it burned like fat; dissolved in hot alcohol, and separated on cooling.

† See Annales de Chimie, T. XLIII, p. 267; T. XIX, p. 295; T. XLIX, p. 250.

‡ There is no similarity between this and animal gelatine except in the mere property of gelatinizing.

§ In families, sugar is added both for taste and to aid in producing the tramulous consistency.

(c.) *Jelly becomes solid by drying*, and that of the tamarind is transparent.

(d.) *It combines* (at least that from the pulp of the cassia,) readily *with alkalies*.

(e.) Nitric acid converts it into oxalic, while little nitrogen is evolved.

(f.) Infusion of galls precipitates it.

(g.) *Destructive distillation affords the usual products* of vegetable decomposition, much pyromucous acid, little oil, and scarcely any ammonia.

(h.) Its ashes afford a little carbonate of potassa, carbonate of lime and oxide of iron.

(i.) *It seems intimately connected with gum*, and probably may be that substance combined with an acid, for by washing with water when laid on a sieve, an acid passes through and a substance like gum remains.*—H.—T.

SEC. VIII.—CAOUTCHOUC.

India Rubber and Elastic Gum.

I. HISTORY.

(a.) First brought to Europe as a curiosity, early in the 18th century, in the shape of bottles, birds, &c. *Obtained in Brazil,† from the native tree, Siphonia elastica,‡* of the family of Euphorbiacæ.§

(b.) *It is afforded by several East India trees*, the principal of which are *Ficus Indica, Artocarpus integrifolius, Tabernamontana elastica, Ficus religiosa*, and *Sapium aucuparium*, &c.||

II. METHODS OF OBTAINING AND MOULDING.

(a.) *On puncturing these plants, a milky juice exudes, which, being inspissated in the air, lets fall caoutchouc.*

(b.) The juice is *white*, but the natives apply it in successive layers on moulds of clay,¶ and dry it in smoke, whence it acquires a black color; when finished, the mould is crushed and falls out.

(c.) *The Tabernamontana elastica,** affords abundance of white juice* which in tight vessels, remains for weeks unchanged; if exposed to the air, or better if acidulated, the caoutchouc†† separates in a clot and leaves a watery fluid.

* The pectic acid, a substance resembling jelly will be mentioned hereafter.

† Condamine in the French Academy, 1736.

‡ Other species of these genera probably afford caoutchouc.

§ The same tree was afterwards found in Cayenne; caoutchouc is the native name.

|| Abundant in a tree on the Arkansas.—Am. Jour. Vol. III, p. 44.

¶ In the shape of little bottles, horses, birds, alligators, &c.

** A climbing plant of *Prince of Wales Island*, and of the *Coast of Sumatra*.

†† Equal in the oldest trees to about 2-3 the weight of the juice.

(d.) *Cloth of all kinds and boots, gloves, &c. are rendered impervious to water by being impregnated with the fresh juice of the Tabernamontana elastica.**

(e.) In South America, vessels for water and other liquids are made of caoutchouc.

III. THE JUICE.

(a.) *The juice in close bottles† was white, turbid, and fetid; it contained masses, spontaneously deposited, resembling the bottles in form, but smaller, soft and elastic.*

(b.) *The juice, in the air, promptly acquired an elastic pellicle, and in oxygen gas or chlorine, a precipitate was hastened.*

(c.) *After the native juice had concreted, the caoutchouc was no longer soluble in its original fluid.*

IV. PHYSICAL PROPERTIES.

(a.) *That which separates spontaneously in close vessels is the purest; it is white or yellowish; when quite pure, it is colorless and transparent; it is a non-conductor of electricity.*

(b.) *As usually seen in the form of bottles, &c. it is brown or blackish; the masses from the East Indies, are in the inside nearly white; tasteless, inodorous,‡ externally smooth, internally rough, sp. gr. 9.33, water being 10.*

(c.) *Soft, pliable, highly elastic, and adhesive, softened in warm water,§ it can be extended to 6 or 7 times its original length, and will recoil with force.*

(d.) *In cold air or water, this property is soon impaired; at 40° it is stiff and would probably become brittle by intense cold, but warmth restores its elasticity.*

(e.) *If a strip of it be quickly extended upon the lip or forehead, sensible heat is perceived, especially at the instant of greatest extension, and cold when it contracts;|| it is referrible to the same general cause which evolves heat by percussion and friction.*

(f.) *Fresh surfaces, especially if warm, will adhere by mere contact and will unite firmly by pressure.*

V. CHEMICAL PROPERTIES.

(a.) *Insoluble, even in hot water, but becomes, by its action, whiter, softer and more elastic, and by boiling, it imparts to that fluid a peculiar smell and taste.*

* Or by being imbued with a solution of the solid caoutchouc properly prepared.

† Examined by Fourcroy in specimens of the juice from Bourbon, Cayenne, and the Brazils.

‡ Except when warmed, when it has a faint peculiar smell.

§ A stout bottle of it may be cut spirally into a thong; after immersion in warm water, it may be stretched 50 feet in length, and if one end is then let go it returns with a quick stroke and may hit a little roughly, those who are in its way.

|| First noticed by Mr. Gough, a blind man of Kendal, Eng.

(b.) *No action by alcohol*, only by boiling in it, the carbon of the smoke is withdrawn; it becomes colorless and the layers are rendered more apparent.

(c.) *It easily melts and looks like tar, but when cold, does not con-
crete nor dry, nor recover its elasticity.* In this state it forms a good
varnish to protect iron from rust.—*A. Aikin.*

(d.) *Very combustible; burns with a bright flame*, and much
smoke, which is a fine lamp black; it forms a brilliant torch, and
in Cayenne is burned for the light; in oxygen or chlorine gas it burns
with increased brilliancy; the odor also is peculiar and aromatic.

(e.) *A burning piece, if suspended, lets fall blazing drops*, and al-
most streams of fire.*

(f.) By destructive distillation, it affords carburetted hydrogen,
but no ammonia, as formerly stated.†

Dr. Ure's analysis gave carbon 90, hydrogen 9.12, and Mr. Fara-
day agrees with him, that carbon and hydrogen are its only elements.

(g.) *Sulphuric acid chars it*, and emits sulphurous acid gas.

(h.) *Nitric acid gives nitrous fumes*, and oxalic acid.

(i.) *Muriatic acid has little or no action.*

(j.) *Chlorine discharges the color*, and renders it opake like
leather.

(k.) *Alkalies exert little action*, but they cause it to become soft
and inelastic; it absorbs ammoniacal gas.

VI. SOLVENTS.

(a.) *Soluble in washed ether*,‡ and previous softening in hot water
facilitates the solution;§ it should be cut into threads, and the vessel
stopped, and in a few days it will dissolve, even in the cold.

(b.) *The solution is brownish and somewhat viscid*; the undis-
solved portions become white and pulpy, and are in a condition to be
easily dissolved by more ether.

(c.) *Dropped on water, it covers the surface with a film*; if the
water is warm, the ether evaporates rapidly, and leaves the caout-
chouc in a state to be easily taken up by a glass rod, when it will be
white, and is readily drawn out into elastic threads. *It is deposited
in a similar manner on cloth*, or any other substance.

(d.) The edges of two pieces of caoutchouc, being dipped in the
ethereal solution and instantly pressed close together, unite perfectly.¶

* If received upon water, they flatten and float like petroleum.

† The large thick pieces of it from the East Indies, when cut, emit a fetid odor
like putrefying animal bodies, and it was once supposed to contain nitrogen, but Mr.
Faraday found none; still, all preceding authors assert its existence in caoutchouc.

‡ For the process of washing, see Ether.

§ Alcohol troubles the solution by attracting the ether.

¶ The use of this solution is limited by the expense and by the rapid evaporation
of the ether, which renders it impossible to lay on an even coating, and at the same
time the brushes are choked; other methods will be mentioned.

(e.) *Soluble in nitric ether*, which, according to some, is the better solvent.*

(f.) *Volatile oils dissolve it with the aid of heat*, and more readily than ether. In oil of turpentine, in the cold, it swells and becomes transparent, and dissolves in two or three days.†

(g.) *Naphtha dissolves $\frac{1}{3}$* , and by evaporation deposits it again unaltered; rectified coal naphtha is now used for this purpose.

(h.) *Oil of Cajuput‡ is an active solvent*; the solution is thick and glutinous, and is decomposed by alcohol, which unites with the oil, while the caoutchouc floats in a semi fluid state, and when washed and dried, it recovers its former properties.

(i.) *Oil of spike and of lavender dissolve caoutchouc.*

(j.) *It dissolves, at a boiling heat, in expressed vegetable oils*, in wax, butter and animal oil, forming viscid, inelastic compounds.

VII. *USES*.—To form flexible tubes, catheters, bougies and elastic bags§ for gases, &c.; to remove pencil marks; by pressure, its elasticity drags along and tears away the fibre of the paper, and with it the crayon mark.

(a.) To form a tube, cut a bottle of caoutchouc into a long single slip; soak it for half an hour in ether to soften it;|| the strip is to be wound spirally around a mould, the edges being in perfect contact, and for security a tape is added; in a day or two the tape is removed, and to complete the junction the tube is immersed in the ethereal solution; boiling water evaporates the ether and leaves a smooth surface.¶

(b.) Dr. J. K. Mitchell, of Philadelphia, has found that caoutchouc bags, by soaking in ether, sp. gr. .765 to .775, for at least four days, can be inflated so that a bag weighing 6 oz. may have a circumference of between 8 or 9 feet; bags expanded in this manner, when filled with hydrogen gas, are balloons.**

To prevent the cohesion of the sides of an inflated bag, powdered starch should be thrown in, either previous to inflation, or before a collapse is permitted. If the inflated bags be hung up until quite dry, they will not again contract and may be cut up into sheets.

* Perhaps with a partial decomposition of the ether, for the solution is yellowish, and, on evaporation, deposits a substance similar to a resin.

† Caoutchouc, 1, oil of turpentine, 5, and dried linseed oil, 48, form a varnish difficult to dry; with wax and boiled linseed oil it is elastic, and is used for balloons.

‡ Distilled in India from the leaves of *Melaleuca Cajuputi*.

§ A sixpenny bag, inflated by the mouth, will supply a blow pipe fitted with a small good jet for 10 or 15 minutes, and a bag of middling size, filled by a syringe, will blow 45 minutes.—J. G.

|| Oil of turpentine or of lavender may be substituted, but is longer in drying; even warm water will answer.

¶ The mould is more easily withdrawn if made a little conical, or if the tube is softened and expanded by immersion in hot water.

** One of which was found 130 miles from its place of ascent. This is the only one, out of seven thus sent up at various periods, which has been heard of.

Gum elastic bags, when softened as above by ether, may be moulded into almost any shape, as, by being drawn over lasts for shoes, and over cylinders for tubes.

Recent experiments by Dr. Mitchell shew, (contrary to the former opinion,) that gases readily permeate caoutchouc, and are thus intermingled.

The following gases, in equal quantities, passed in the following times,* through a gum elastic membrane, to join atmospheric air.

Ammonia, 1 min.; sulphuretted hydrogen, $2\frac{1}{2}$ min.; cyanogen, $3\frac{1}{4}$ min.; carbonic acid, $5\frac{1}{2}$ min.; nitrous oxide, $6\frac{1}{2}$ min.; arseniuretted hydrogen, $27\frac{1}{2}$ min.; olefiant gas, 28 min.; hydrogen, $37\frac{1}{2}$ min.; oxygen, 113 min.; carbonic oxide, 160 min.; nitrogen at least 180 minutes.

Dr. Mitchell has discovered that caoutchouc, after it has been softened in ether, may be dissolved by oil of sassafras, so as to be applied by a brush, and when dry it will be again elastic;† it will adhere to glass or porcelain, and come off in a sheet when wet; this solution will cause two surfaces of caoutchouc to unite.

It is recovered also, unchanged, from a state of solution in petroleum. When dissolved in the naphtha of coal,‡ it may be brushed over cloth, and two surfaces, thus prepared, being placed together are compressed between the rolling cylinders and thus united, and the cloth becomes impervious to water.—H. The sheet caoutchouc may be prepared from the same solution, and it is now much used for making tubes and joining apparatus. By simply cutting a folded sheet with warm scissors, a joining of the edges will take place, which may be perfected by pressure of the nails.§

(c.) An imitation of caoutchouc has been made by preparing oil in a very drying state by oxide of lead, and spreading it with a brush on any surface, when being dried by sun or smoke, it will resemble the elastic gum, and burn like it; it has been used for catheters and bougies; (*Ure*,) they have not however the permanency of the real caoutchouc and are soon roughened or destroyed by use.||

(d.) Dr. Comstock, of Hartford, Con. makes bags called life preservers, of cloth imbued with elastic gum; they are braced around the body beneath the arms, and by a stop cock, they are blown up by the lungs; they will sustain a man with his head and shoulders above water.

* At the same relative rates, the gases pass through animal membranes. The power of permeation is so great that a column of 63 inches of mercury placed in a limb of an inverted syphon, burst the membrane and terminated the research.

† Franklin Jour. Vol. V, p. 122.

‡ Ann. Philos. Vol. XII.

§ See Faraday's Manipulation, § 416.

|| The late Mr. Eli Whitney, of New Haven, who had important reasons for procuring the best instruments, could obtain none from London that were genuine; in his opinion none of them were made of caoutchouc.

There is a mineral caoutchouc found at Derbyshire, Eng.; it has properties considerably resembling those of the vegetable; it is scarcely necessary to add that neither of them is alimentary.

SEC. IX.—FIXED OILS.

1. *Oils are distinguished into fixed, or fat, and volatile or essential*; the fixed oils are obtained by pressure, sometimes aided by heat, and at other times without pressure, by the action of boiling water; the volatile by distillation, at the temperature of boiling water or of boiling alcohol.

2. *Fixed oils are found chiefly in seeds*, and mostly in those of two cotyledons, as linseed, almond, beech nut, poppy seed, rape seed, &c.

I. PROPERTIES.

(a.) *Unctuous, stain paper permanently; generally fluid; somewhat thick, scarcely viscid*; generally congeal at a moderate cold, some freeze at 32° , others below that degree, and others are never fluid at atmospheric temperatures.

(b.) *The latter are called vegetable butters*, e. g. palm oil, oil of cocoa nut, of the laurel berry, nutmeg, &c.

(c.) *Inspid, or with a mild taste; sometimes nauseous or acrid*.*

(d.) *Colorless and transparent*, or at first greenish, becoming yellow by keeping.

(e.) *Sp. gr. generally such that they swim on water but sink in alcohol*.

(f.) *Water has no action on them*; they are miscible with it by agitation but separate by repose.

(g.) *Oil dropped upon water spreads over the surface denoting some attraction*.†

(h.) *Not volatilized without decomposition*; ebullition does not generally begin under 600° , but an inflammable vapor rises under 500° .

(i.) *The condensed oil is empyreumatic and is rendered more limpid and volatile*; carburetted hydrogen and carbonic acid, holding oil in solution are evolved, also an acid fluid, and charcoal is left.

(j.) *Successive distillations attenuate the oil still more, till finally it is all volatilized and decomposed and various products formed*.‡

(k.) *If driven in vapor, through an ignited tube, the decomposition is more complete, and the quantity of the gas much greater*.

* Or having some peculiar flavor derived from foreign matter or from the mode of preparation.

† Butter is added to aqueous fluids to prevent their boiling over, and oil is said to be poured on waves to quell them.

‡ For some very curious results, see Ann. de Ch. et de Ph. Vols. XXXI, XXXII and XXXIII.

(l.) *Heated in an open kettle, the color deepens, fetid inflammable vapor escapes and it becomes a drying oil** and in the air forms a solid tough varnish.

(m.) *The air acting upon oils that are not drying, especially if warm, produces rancidity*; they abstract oxygen,† become thicker, and reddened vegetable blues; they become rancid much sooner if placed in oxygen gas.

(n.) *Rancidity is counteracted by churning with warm water*, renewed till it comes off clear; oils and butter have been kept in water for fifty years perfectly sound.—*Black.*

(o.) *Some oils are rendered colorless and some deeper colored by becoming rancid*; the bright yellow of oil of olives is thus discharged.

(p.) *Spontaneous combustions result from the rapid absorption of oxygen by drying oils*, especially when mixed with other combustibles.‡

(q.) *Combustion of oil takes place near the point of boiling or of decomposition, and vaporization and ignition are necessary to sustain it*; hence the utility of a wick which draws up the oil by capillary attraction.

Composition.

(r.) *The products of the combustion are water and carbonic acid.* Lavoisier found in 100 parts of olive oil, 79 carbon, 21 hydrogen. Potassium is oxidized by oils and evolves hydrogen gas from them, which proves that they contain oxygen.

Gay-Lussac and Thénard found olive oil to be composed of carbon 77.213 + oxygen 9.427 + hydrogen 13.360 = 100, corresponding very nearly with 10 equiv. of carbon, = 60 + 1 of oxygen = 8 + 11 of hydrogen = 79, its supposed equivalent; the hydrogen is in excess 12.075 pr. ct. beyond what is necessary to form water.—H.

* It is supposed that secula and mucilage are decomposed, water volatilized, some oil dissipated and the rest oxygenized; metallic oxides, especially oxide of lead, aid in producing this effect. Drying oils, boiled on a little litharge without water, become thicker and more drying than before. For safety the oil is often boiled out of doors; rain falling into the kettle produces hydrogen gas in the proportion of 1 pint to a drop of water, and the oil is dashed about with slight explosions.—*Black.*

† Linseed oil, without disengaging any carbonic acid, absorbed 12 volumes of oxygen gas in 4 months. Drying oils do not become rancid, and by absorbing oxygen they approach to the nature of resins.

‡ These accidents were formerly frequent in the Russian navy and arsenals; on inquiry it appeared that if hemp, flax or linen cloth, or fine charcoal wrapped in linen, be steeped in drying oil and lie confined and somewhat pressed in a heap, combustion results; it occurred once in 16 hours, once in 9.—*Journal de Physique*, Vol. XXII, p. 111. *Rep. Arts*, Vol. III, p. 96.

N. B. Black wad (earthy oxide of manganese) and drying oil, when used as a paint, are apt to burn. Coffee, roasted with butter in it, once took fire in this place, (New Haven,) some hours after it was set away in a cellar.

The oiled refuse cotton sometimes gets on fire, in cotton mills. Four pounds of suet, rather greasy than firm, and two pounds of linseed, hemp seed or other drying oil, being mixed, after a few hours will grow warm, and, if wrapped in flannel, the heat increases to inflammation.

(s.) Hydrogen is slightly absorbed by oils, and *newly prepared charcoal*, especially animal, *bleaches* and purifies them.

(t.) *Phosphorus is dissolved by digestion* and forms phosphorized oil, which in the air is luminous.*

(u.) *Sulphur dissolves in boiling oil*; the solution is viscid, red, fetid and acrid, and is called in the shops balsam or ruby of sulphur; it emits sulphuretted hydrogen gas.

(v.) *Alkalies unite with oils and form soaps*; see animal oil for the theory of saponification and the separation of oils into a solid portion, *stearin*, and a fluid *elain*.†

(w.) *Oxides of metals unite with oil by heat and by trituration*. Common plaster is prepared, by boiling 2 parts of olive oil with 1 of litharge and a little water, to prevent scorching; oxides of bismuth and mercury afford similar compositions.

(x.) *Oils aid in the oxygenizement of some metals*; copper, oiled or greased, acquires a green color.

(y.) *The strong acids generally decompose the oils*.

(z.) *Hot sulphuric acid carbonizes them*; water is produced, and sulphurous acid and sometimes even sulphur is evolved. With certain proportions, a kind of soap is formed, which lathers with water.

(aa.) *Nitric acid acts with less violence*, and if cold and colorless, only thickens the oil and renders it white; but *with hot and fuming nitrous acid the action is rapid*, especially on the drying oils, and it sometimes inflames them.‡

(bb.) *Chlorine thickens and bleaches the oils*, and they pass to the state of wax.

(cc.) *Oil combines with sugar* or simple mucilage and fecula, and forms an emulsion, which, especially with mucilage, is often used in pharmacy.

(dd.) *Alcohol dissolves some fixed oils*; castor oil is soluble in every proportion, in alcohol of sp. gr. .820, but not in that which is weaker.§ Four fluid oz. of sulphuric ether, sp. gr. .756, dissolve 1½ fluid oz. of oil of almonds, 1½ of olive oil, 2 of linseed oil, and castor oil almost without limit.

II. SOURCES.

(a.) *Oils are abundant in the vegetable kingdom*, and are *found chiefly in the seeds and fruit*, and most when near maturity.

(b.) They are bruised or broken and pressed in a hempen bag, and foreign matter is permitted to subside.

* Vol. I p. 421, z.

† In olive oil at 44° F. there is elain, 72, stearin, 28; in almond oil, 76 and 24; in rape oil, 54 and 46.

‡ Dried linseed oil ropes out of the mouth of a narrow vessel, and produces an overpowering smell.

§ Phil. Trans. 1811, p. 264. Castor oil has been used to adulterate costly essential oils, especially oil of cloves.

(c.) In some instances, the seeds are gently roasted, and the oils are thus rendered partially acrimonious and empyreumatic; they are then less liable to congeal, and more prone to dry in the air.

III. PRINCIPAL FIXED OILS.*

OLIVE OIL.—From the fruit of the olive tree, (*Olea Europea*.) the fruit is crushed in a mill so as not to break the nut: several qualities are obtained by repeating the process, the first is the best and is used as butter; the inferior sort is burned for light or made into soap.†

CORNEL OIL.—From the pulpy part of the berries of the *Cornus sanguinea*; color bright green; no unpleasant flavor.

ALMOND OIL.—From both the sweet and bitter almond; color lightish green or yellow; little used except in medicine, as it is dear.

POPPY SEED OR PINK OIL.—Cold drawn from the seeds of the large white poppy, in France, Netherlands, and Germany; a natural drying oil; employed as a food like olive oil, which is often adulterated with it; unfit to burn in a lamp; used in varnishes; has no narcotic properties.

LINSEED OIL.—The flax seed is torrefied,‡ ground and pressed. The cold drawn oil is yellow, the hot drawn is red, and is a drying oil, especially if boiled with litharge.

HEMPSEED OIL.—Resembles the preceding; color green.

OILS OF MUSTARD SEED, COLE SEED, RAPE SEED AND SUNFLOWER SEED.—Less colored than the two preceding; cheap, and much used by the leather dressers and to preserve wool from moths and insects.

NUT OIL.—Chiefly cold drawn, from the kernels of the walnut and hazle nut; finest in the warm climates of Europe; when recently drawn, has the fine nut flavor; the hot drawn is very drying and much used in painting; bears the weather better than any oil.

BEECH NUT OIL.—Cold drawn from the kernels of beech nuts; resembles olive oil.

OIL OF BEN.—*Oleum Balani* of the ancients. From the seeds of the *Guilandina Moringa* of Ceylon, Ethiopia, &c. Oil yellowish, limpid, inodorous; does not become rancid in the air; used by the Italians as the basis of perfume oils.§

VEGETABLE BUTTERS.—**BUTTER OF CACAO.**—From the chocolate nut, the fruit of the *Theobroma Cacao*; extracted by boiling water;

* Aikin's Dict.

† *Oil of bricks* is olive oil distilled from bricks which have been ignited and quenched in it; used by the lapidaries and stone-cutters to hold their fretting powders.

‡ To destroy mucilage, &c.

§ Alternate layers of cotton, soaked in ben oil and flowers of jasmine, violet, orange, &c. in a covered dish, are placed in hot water or in sunshine, for a few days; when the oil is pressed out it is impregnated with the aromatic qualities of the flowers.

when cold, concretes on the surface ; has the delicate flavor of chocolate ; not disposed to rancidity ; used as a food, and in unguents and medicated soaps.

PALM OIL.—Chiefly from the species *Cocos butyracea* and *Elæis Guineensis*. Hot water disengages the oil, which rises and concretes ; used in the West Indies and in Africa as food ; in Europe as medicine and in the composition of the best yellow soap.

IV. USES OF OILS.—Basis of paints, being triturated and mixed with metallic oxides ; with resin and turpentine they form *fat varnishes*. Drying oil with lamp black forms printers' ink. Some are used in medicine and some for food.

Castor oil from the *Ricinus communis* is a valuable medicine and a single drop of the oil of the Croton Tiglium produces similar effects with great energy.*

Oil is freed from mucilage by agitating it with 1 or 2 pr. ct. of sulphuric acid ; the matter coagulates, it is washed with $\frac{3}{4}$ as much water as oil, and strained through cotton. By this process, common fish oil is purified, for combustion in lamps.

SEC. X.—WAX.

I. ORIGIN.

(a.) *A product of vegetable life, and bees form* as well as collect it.

(b.) Pollen, being visibly collected by bees on their thighs, it was supposed that they form wax from it, but wax is formed (without pollen) from honey, molasses or sugar, on which bees have been fed when confined in houses ; but where they were fed with pollen and fruits no wax was formed.†

(c.) *Wax is also a product of vegetation ;*‡ It is the varnish of the leaves of vegetables as of the cabbage, &c. and of the rind of plums, oranges, &c. which prevents their being wet ; it exists in the secula of some plants as the house leek, in which it abounds.

(d.) *The berries of the Myrica cerifera of the United States,*§ afford it in abundance and boiling water melts it|| off from the seeds.

II. PROPERTIES OF WAX OF BEES.

(a.) *Color yellow, smell aromatic,* but inodorous and colorless after bleaching.

* Eng. Journal of Science, Vol. XX. p. 231.

† Huber, Journal de Phys. Tom. 58.

‡ The pollen feeds the larva of the Bee and the latter forms the wax. Pollen does not possess the properties of wax, although it contains it.

§ Found from the great lakes to Florida.

|| White Lac is by some considered as a variety of wax ; it is supposed to exist also in common lac combined with resin, coloring matter and gluten.

(b.) *Bleached by exposure to sun and air* in thin pieces or ribbands;* *bleached also by light alone* between two plates of glass, the edges being protected from the air.

(c.) *Sp. gr. when unbleached*, from .9000 to .9650; if bleached, from .8203 to .9662.

Insoluble and unalterable in water.

(d.) *Fusible at 142°*; at 155° if bleached; forms a transparent fluid, but becomes opaque again on cooling.

(e.) *At ignition, burns with a clear white light*, and forms water and carbonic acid; may be made to boil, affording distilled oil and some stearic acid.

(f.) *Formed into candles* with the addition of a little tallow; a smaller wick answers than in the case of tallow, because the wax is less fusible; the candle needs no snuffing.

(g.) *When decomposed in close vessels, gives products similar to those obtained from the decomposition of oils.*

(h.) *Composition*.—Carbon, 82.28 and hydrogen, 17.72.—Lavoisier.

Carbon,	81.784	80.69
Oxygen,	5.544	7.94
Hydrogen,	12.672	11.37

100.—G. L. 100.—Ure, and corresponding nearly with 13 equiv. of carbon, 78 + 1 oxygen, 8 + 11 of hydrogen, 11=97.

(i.) *Alcohol has no action in the cold*; at ebullition dissolves $\frac{1}{10}$ its weight, deposits most of it on cooling, and the rest is separated by water; ether is affected in a similar manner.

(j.) *By boiling combines with the fixed alkalies*, and with ammonia, and forms a soap.†

(k.) *Oils by fusion unite readily with wax*, and form a soft compound called cerate.

(l.) Cold volatile oils act but feebly; hot oil of turpentine dissolves wax, but on cooling precipitates a soft solution.

(m.) *Acids have but a feeble action*; the diluted mineral acids, in a few hours, discharge the color from thin pieces.

(n.) *Although the usual method of bleaching is by light, chlorine is now employed with success*‡ but as the chlorine combines with the wax, its odor is diffused in burning, and in preparing wax for candles, it is necessary to renounce this method.—G. L. Cours, &c.

* See Aikin's Dict. Wax adulterated by tallow or fat is more fusible but opaque white, not semi-transparent; boiling alcohol dissolves the wax but not the tallow.

† A compound of bees wax 20 parts with 1 of soda was the Punic wax of the ancients, used as the basis of colors and in "encaustic painting."—Murray.

‡ I have received fair specimens bleached in this way from Norwich, Con.

III. MYRTLE WAX,* from the *Myrica cerifera*.

- (a.) Color greenish, sp. gr. 1.015, and sinks in water.
- (b.) Melts at 109°, burns with aromatic odor, and little smoke.
- (c.) More soluble in alcohol, ether, and the alkalis than bees wax.
- (d.) Caustic potash dissolves and whitens it, but it has not been bleached in the sun and air.

The name *cerin* was given by Dr. John to that portion of myrtle or of bees wax that is soluble in boiling alcohol or ether, but insoluble in them when cold; while that part which is not soluble in them at all he called *myricin*.

IV. MISCELLANEOUS.

(a.) The Chinese manufacture candles and ornaments from a wax which they extract from various vegetables.

(b.) New bees wax is nearly white but grows yellow in the hive, and ultimately brown; the finest is made in dry hilly countries, that of wine countries is inferior.

(c.) The honey is pressed out and the wax being melted by hot water, in clean coppers, is strained through cloth bags and cast into cakes.

(d.) A peculiar vegetable wax is obtained in Brazil which, with $\frac{1}{15}$ of tallow or $\frac{1}{4}$ of bees wax, makes very excellent candles.†

(e.) Wax resembles a dense fixed oil, but it obviously differs in some particulars.

V. USES.—The best material for candles; used in cerates; as a lute and cement in laboratories, being little affected by acids; in sewing to make thread smooth; not used for food although it is innocent, being often swallowed with the honey which it contains.

SEC. XI.—VOLATILE or ESSENTIAL OILS.

I. NAME and ORIGIN.

(a.) So called from their volatility and from their containing the most active properties of vegetables, especially in relation to taste and smell; the odor of fruits flowers and of vegetables generally resides in their volatile oils.

(b.) Not so abundant as some of the proximate principles; in many vegetables, not found at all, and exist chiefly in the aromatic plants.‡

(c.) In some, confined to the flowers, the fruit, the leaves or bark; in others, found in several of these parts, and in a few, diffused through the whole structure.

* See an analysis, by the late Prof. Dana, Am. Jour. Vol. I, p. 294.

† Brande, Phil. Trans. 1811, p. 268.

‡ As most vegetables have odor, they evidently emit something volatile although it may be too fugitive for condensation or detection.

(d.) *Least abundant in the cotyledons of the seed, the peculiar seat of the fixed oil, while the husk or cover of the seed almost always contains more or less volatile oil, which is a defense against insects.*

(e.) *The quantity of oil depends much on the age and vigor of the plant, and on climate, soil and season. Some yield most when in full blossom; others when going to seed. Roots afford most, just before they send forth their radicles in the spring; woods at the beginning of winter.**

(f.) *Some odoriferous flowers and plants afford† no volatile oil, by distillation, because our methods are imperfect, and the proportion of the oil is minute, although it may be very active and strong; e. g. roses and orange flowers, in small quantities, afford no oil, although it is obtained from larger quantities.‡*

II. MODES OF OBTAINING.

(a.) *Volatile oils are discovered by their odor; in general they cannot be obtained by pressure, except a few which are contained in distinct vesicles obvious to the naked eye, as in the rind of the orange, lemon or bergamotte orange; or, the vesicles are discovered by the microscope, as in nutmegs,§ angelica, and masterwort.*

(b.) *The raspings of the outer, yellow rind of the orange, are pressed between glass plates and the oil exudes.||*

(c.) *The common mode of obtaining volatile oils is by distillation with water. Bark or wood is rasped or shaved, and both these and dried plants are macerated, rammed into a still and covered with water, which is made just to simmer, and the oil distils over and is condensed on the water or sinks beneath it; the water dissolves some of the oil and is called distilled or aromatic water, as the oil is called distilled oil.¶ The addition of salt raises the temperature a little, so that more oil is obtained.*

* Nich's Dict. Maceration of green vegetables is injurious; it is useful with dry and solid bodies, and common salt is added to prevent putrefaction.

† As the violet or jessamine, lilies, hyacinths, clove July flowers, bloom of the lime or linden tree, lilies of the valley, &c.

‡ By the 100 lbs. all the odorant vegetables which contain it would probably afford volatile oil, because, even those from which, in small quantities, we extract none, afford odorant water in the distillation, while the plant becomes inodorous.

§ On cutting the nutmeg the oil instantly exudes.

|| *Attar or oil of roses is obtained in India*, by filling a clean cask or large glazed earthen jar with rose leaves which are covered by spring water; the vessel stands in the sun two or three days, and is taken in at night; after the third or fourth day, the oil floats in particles, and in a week a thin scum is taken up by cotton on a stick and squeezed into a small vial.

In the same way the oil of *ben* absorbs the fragrance of the blossoms of the violet, mignonette, jasmine and the hyacinth; that of the tuberose, and of all the scented liliaceous plants is thus obtained, although too minute in quantity and too destructible by heat to be procured in any other way. The perfumed oil is, by agitation, combined with an equal bulk of alcohol, and the latter being mixed with water, the oil floats and is taken up by cotton.—*Likins*.

¶ Alcohol, unctured with essential oil, is called spirit; thus we have lavender spirit and lavender water.

III. PROPERTIES.

(a.) In general, *more active than fixed oils, odoriferous, volatile, inflammable; aromatic; taste hot, acrid and pungent; oil of cloves caustic to the tongue and other delicate parts; oil of peppermint leaves a sensation of coldness.**

(b.) *Most of them float on water; a few, from the aromatic plants of hot climates sink, as oil of cloves, and oil of cinnamon, and sassafras. Oil of turpentine is of the sp. gr. .868 at 71°, oil of sassafras, the heaviest known, is 1.094.*

(c.) *Consistence various; some are limpid like water, some thick and glutinous like expressed oils, or butter, and even in a few cases, more solid, as anise, fennel, and rose.*

(d.) *Some congeal at 30° Fah.; some are fluid at 17°; in congealing they crystallize.†*

(e.) *Color various; more commonly light yellow, by age yellowish brown; sometimes blue and green.*

(f.) *Volatilized with water below 212° without decomposition; sophistication with fixed oil is discovered by their leaving a greasy stain on paper.‡*

(g.) *If heated with clay or sand, or vaporized through a red hot tube, they are decomposed, producing inflammable gases, carbonic acid and charcoal.*

(h.) *Burn without a wick, with much white flame and dense smoke; they require more oxygen than fixed oils, and carbonic acid and water are the products.*

(i.) *Composition: they are composed of carbon and hydrogen, and with occasionally some oxygen.*

According to Dr. Ure,

Carbon, 14 equiv.	-	-	-	84	82.35
Hydrogen, 10	-	-	-	10	9.80
Oxygen, 1	-	-	-	8	7.85
				102	100.§

* Some are poisonous, as the oil of bitter almonds and of the *Prunus Lauro-cerasus*, of which a minute dose kills animals very speedily; one drop, on the tongue of a cat, was fatal in five minutes, and a tube wet with the oil and touched to the tip of the tongue of Mr. Brodie, (see Phil. Trans. 1811,) produced alarming effects. The empyreumatic oil of tobacco is a violent poison, and as it is produced by distilling tobacco leaves, at a heat above 212°, there can be no doubt that it is generated, and of course inhaled, in smoking tobacco.

† This appearance must not be confounded with that of the benzoic acid, or something similar to it, which some oils deposit on exposure to the air.

‡ Sometimes from age and on account of a resinous matter, they leave a stain although not adulterated; but then the stain is not greasy, and the paper may be written upon.—*Prof. J. R. Coze.*

§ Oil of turpentine, bergamot, citron and rose, when recently obtained, contain no oxygen, and are less soluble in alcohol than other oils that contain oxygen; water readily precipitates them, while the oil of lavender, which contains oxygen, is so soluble in alcohol as not to be precipitated by water.

If purified by alcohol, oil of turpentine appears to consist of carbon and hydrogen only, and to approximate to naphtha. According to Gay-Lussac, pure oil of turpentine consists of 88.348 carbon 11.652 hydrogen, corresponding to 2 vols. vapor of carbon and 4 carburetted hydrogen. A very pure oil is obtained by distilling it with water. The vapor of oils is very dense; it may be five times as dense as that of air, and, in the case of oil of turpentine, even more.

(j.) *Volatile oils absorb oxygen gas,** and become inodorous and inspissated† both in bell glasses and in the open air.‡

(k.) *Oils, depraved by age, are improved by redistilling them with water,* especially with a little ether or alcohol; the volatile part rises, and the resinous remains.

(l.) *Soluble in alcohol, in various proportions;* the solution is decomposed by water; it becomes milky, and the oil gradually rises; soluble also in ether.

Acids act with more energy on volatile than on fixed oils.

(m.) *The sulphuric generates heat, blackens and effervesces with sulphurous gas,* and sometimes produces combustion; 3 or 4 parts of the acid and 1 of the oil form a soapy compound.

(n.) *Nitric acid, if strong, inflames the volatile oils,* especially with $\frac{1}{2}$ or $\frac{1}{3}$ of sulphuric acid, (Vol. I. p. 450, t;) great care is necessary.

(o.) *With a slower action, other acids and resin are formed;* in both cases, much gas is evolved.

(p.) *Muriatic acid gas, passed through oil of turpentine, cooled by salt and ice, is absorbed,* to the amount of $\frac{3}{4}$ of the weight of the oil, and being drained or filtered, affords a crystalline substance resembling camphor, it appears to be a compound of 2 volumes of the acid gas and 3 of the vapor of the oil.§ It smells like oil of turpentine and muriatic acid gas, and is nearly identical with common camphor, which Thénard supposes may be a compound of volatile oil and a vegetable acid.

(q.) *Volatile oils detonate by friction with chlorate of potassa, and some take fire in chlorine gas.*

† Anise seed oil absorbed in two years 156 times its volume of oxygen gas and produced 56 volumes of carbonic acid; oil of lavender absorbed, 52 volumes, in 4 winter months, and gave only 2 volumes of carbonic acid.

‡ Hence one reason why paints vitiate the air, especially when they contain volatile oils, as oil of turpentine, which is frequently mixed with them; but Dr. Hare suggests that it is more probable that some of the paint is volatilized.

§ Water is formed and benzoic acid, (or crystals resembling it) deposited; and the greater part, especially in the sun's rays, turns into a resinous body. Camphor is obtained from some of the volatile oils, and intense cold causes a deposit of crystals, only slightly soluble in water, as has been already stated; dropped on boiling water, their odor is quickly diffused through a room.

|| Ann. de Chim. Vol. 51, p. 270—Memoires d'Arcueil, Vol. 2, p. 26, and Thénard's Chem. 5th. Ed. Vol. IV. p. 92. All the essential oils give camphor with the muriatic acid gas and with oil of citron it is solid.—G L.

(r.) *They combine, reluctantly, by long trituration with fixed alkalies.**

(s.) *Liquid ammonia unites, sparingly, with the essential oils; readily when they are dissolved in alcohol.*

(t.) *Sulphur, by digestion, produces sulphurized oil which is yellow or brown and fetid, and is often called balsam of sulphur.*

(u.) *Phosphorus, in the same way, gives a fetid phosphorized oil, luminous in the dark, and which causes objects, on which it is spread, to shine.†* Potassium, by being heated in volatile oil, becomes potassa, and carbon falls.

(v.) By mucilage or sugar, essential oils are suspended in water.

Remarks.—Adulteration of other oils with oil of turpentine is discovered by the smell, when they are rubbed in the hands; if depraved by alcohol, they become milky with water, and if by fixed oils, they leave‡ a greasy spot on paper, from which, when heated, a pure volatile oil will evaporate and leave no stain.

By long exposure to the air, volatile oils approach to the character of resins.

Oil of turpentine is the most important of these oils; it boils at 314° or 316° Fah. and a second distillation is necessary to its purity. Among the other oils, those best known are oil of "caraway, cloves, peppermint, nutmeg, anise, lavender, cinnamon, and citron."

The volatile oils, especially that of turpentine, are used in forming varnishes; in medicine; in perfumes; to kill insects; to tip the wicks of candles before they are lighted, &c.

The effluvia, arising from flowers in consequence of the volatile oils which they exhale, are unhealthy in a confined room.

Volatile oils are generally composed of a solid and a fluid part, which may be separated by cold, and by pressure through paper; this fact will be mentioned again under the animal oils.

The citron oil is very efficient in removing grease spots from clothes and other stuffs.

The volatile oils are too numerous to be cited; for a copious table see Aikins' and Nicholson's Dict. and Thénard's Chem. Vol. IV.

Birch oil is an empyreumatic oil, prepared in Russia, by charring birch wood in a close oven; the oil floats on an acidulous liquor that comes over; it has a peculiar smell which is very offensive to insects, and hence it is used in dressing Russia leather.—Aikins.

For a notice of a new crystalline substance, obtained from oil of turpentine that has long been exposed to the air, see Ann. de Ch. et

* Starkey's soap was formed by oil of turpentine or oil of juniper and potassa. Alkalies and alkaline earths have a peculiar action upon oil of cloves. (Ann. de Ch. et de Ph. Vol. XXXV, p. 274.)

† The sulphur and phosphorus fall in crystals from the above solutions

‡ As already observed, p. 440, (f.)

de Ph. Vol. xxxi, p. 442; and for another new body, from oil of orange flowers, see Id. Vol. xl, p. 83.

SEC. XII.—CAMPHOR.

I. ORIGIN AND NATURAL HISTORY.

(a.) *Contained in many aromatic plants and essential oils*; most of that of commerce comes from Borneo or Sumatra, and is *extracted chiefly from the Dryobalanops Camphora*, a large wild forest tree, whose leaves, when bruised, emit a camphoric odor.

(b.) The camphor is found concreted, in veins and vesicles, in the old trees of the above species, and sometimes forms masses, in the heart, of from 12 to 18 inches long; it is extracted by knives or rasps, and purified by soap and water; the younger trees yield the camphor, only in the state of oil, which is ultimately converted into the solid substance.

In Japan and China, it is *found*, although less abundantly, in the *Laurus Camphora*.

II. EXTRACTION, from the *Laurus Camphora*.—*The roots,* branches, leaves, and twigs*, in pieces, are *suspended* in a net over water, in an alembic, whose capital contains ropes of straw, upon which the *vapor of the camphor, raised by the steam* of boiling water, is *condensed* in impure semi-crystalline masses, which are exported in canisters, under the name of crude camphor.†

III. PURIFICATION.‡

(a.) *In the arts, by sublimation,§* in pear shaped vessels of glass;|| placed in hot sand, the mouths being loosely stopped by a coil of paper, which should be moved occasionally, to prevent choking and explosion¶ and inflammation of the volatilized vapor, which sometimes happen, with great hazard to the people and buildings.

(b.) *The camphor boils, rises, and is condensed* above, and the vessel is broken to get out the product.**

* The roots are said to afford the most camphor.

† *Other sources*.—*Found in other species of Laurus*, cinnamon, sassafras and cassia; also, in the flowers of *Anemone pratensis*; in the roots of galangale, zedoary, and ginger; in the seeds of cardamom and long pepper, oriental mint, abrotanum, milfoil, daisy, juniper, rosemary, *Salvia camphorata*, lavender, hyssop, clary, maudlin, marjoram, &c.—*Black*.

Essential oils afford camphor; it has been extracted from those of juniper, sage, hyssop, thyme, peppermint, rosemary and lavender, and is probably contained in them all. Slow spontaneous evaporation, at about 57°, deposits crystals from oil of rosemary, 6.25 per ct.; oil of marjoram, 10.14 per ct.; oil of sage, 21.06 per ct.; oil of lavender, 25 per ct.

‡ Formerly an art kept secret by the Venetians, and afterward by the Dutch.—The camphor may be dissolved in alcohol, the spirit evaporated, and the camphor melted into a cake, but this however does not separate the resin.

§ 1 oz. of lime, to 1 lb. of camphor, is added to detain the oil, but it is said no addition is necessary.

|| Neck 1 or 1½ inch long, aperture about 1 inch, about 4 high and 11 in diameter.

¶ See Hembel's Note, Edin. Encyc.

** It may be done for experiment, in a Florence flask.

Much practical skill is requisite, to preserve the vessel at the proper temperature; if too hot, the camphor melts and falls back; if too cold, it condenses in a voluminous snow, instead of a firm cake; it should be kept fluid. Camphor may be distilled into a tinned copper receiver, made in hemispheres, which separate and thus release the cake.*

IV. PROPERTIES.

(a.) *Camphor of commerce is in hemispherical cakes.*

(b.) *White*, transparent, granular, foliated or striated; slightly *unctuous*; somewhat *tough* and compressible; *crumbles*, between the fingers.

(c.) *Odor diffusive*, penetrating, fragrant, peculiar, and highly *refreshing*; *taste warm*, and rather bitter.

(d.) *Sp. gr.* 0.999; it just floats on water.

(e.) *Very volatile*, by sublimation, crystallizes in hexagonal plates, or pyramids, evaporates, and in time is lost in the air.† It is volatilized in the shop windows and crystallizes in the upper part of the jar. By exposure, an angular fragment becomes round; between 100° and 150° it sublimes in close vessels, unchanged.

(f.) *Fusing point* 302° F. It maintains the ignition of a platinum wire, in the same manner as ether or alcohol.

(g.) *Burns vividly, with little or no residuum*, much smoke and white homogeneous light.‡

(h.) *More brilliantly still in oxygen gas*, producing carbonic and camphoric acid.§

(i.) *Composition*:—vaporized through an ignited tube, it is decomposed, producing carburetted hydrogen, carbonic acid, &c. According to Dr. Ure, its constituents are,

Carbon	10 equiv.	-	-	-	60	78.02
Oxygen,	1	-	-	-	8	10.40
Hydrogen,	9	-	-	-	9	11.58

77 100.

(j.) *Pieces of camphor floating on water*, are readily kindled and burn a long time, leaving a dish-shaped mass; if small they *move with rapidity*, owing to a solution, at the line of junction between the cam-

* Ann. de. Ch. et de Ph. Vol. XVIII. p. 78.

† Powdered camphor, spread thin, loses not over 50 pr. ct. at 52° in 16 weeks; but the ratio of volatilization is very rapidly increased by increase of temperature: it is more rapid in a moist than in a dry air.

‡ Which is said by Dr. Black (Lectures) to "consist of the same proportion of colored rays with that of the sun, and that all delicate colors which appear different by candle light appear of the proper color when illuminated by camphor."

§ If done in a glass globe over water, the latter is impregnated with the acid and with camphor.

phor, air and water, where, an oily liquor produces these motions *mechanically*, as appears from the fact that the camphor dissolves, and a cylinder of it partially immersed, is cut through at this line ; a drop of oil on the water, stops the currents.

(k.) *Water* has little action, but by trituration and heat, it *takes up enough to acquire both taste and smell; mucilage and sugar enable water to suspend camphor, in a kind of emulsion.*

(l.) *Alcohol is its most effectual solvent* ; in the cold, it dissolves $\frac{1}{4}$ or $\frac{1}{2}$; if boiling, $\frac{1}{4}$ or $\frac{2}{3}$ of its weight, and most of the excess is deposited again on cooling ; the solution is acrid and even caustic.

This is the usual medicinal solution.

(m.) Brandy or alcohol, saturated with camphor, deposits, by mere natural changes of temperature, even in close vessels, beautiful plumose crystals, as in the weather glasses ; they appear and disappear.

(n.) *The spiritous solution is decomposed by water* ; if added slowly, the camphor crystallizes dendritically.*

(o.) Camphorized alcohol and sulphuric acid, distilled in equal quantities, give camphorized ether.

(p.) *Camphor is soluble in sulphuric ether*, and probably in all the other ethers ; water separates it.

(q.) *Oils*, expressed, volatile and empyreumatic, *combine with camphor.*

(r.) *Resins and balsams are thus converted into soft masses*, that are very soluble in alcohol, and even copal is thus dissolved.

ACIDS.

(a.) *Carbonic acid, in Nooth's or other similar apparatus, dissolves camphor* in considerable quantity, and forms a powerful camphorated water, used in fevers and mania ; it gives a good solution of camphor, without alcohol.

(b.) *Acetic, fluoric, and muriatic acids, dissolve a considerable proportion of camphor*, but it is precipitated by water. It has been already mentioned, that camphor is produced by the action of muriatic acid gas upon oil of turpentine.

(c.) *Strong sulphuric acid dissolves camphor largely*, even in the cold ; the compound is soluble in alcohol, but water precipitates the camphor, little altered.

(d.) *Cold nitric acid acts in the same manner*, and the solution shews two distinct fluids, the upper yellow, and oily, called acid oil of camphor ; it is soluble in alcohol, but the camphor is precipitated by water and alkalies ; the other is a watery mixture of camphoric

* The spiritous solution dropped into water precipitates the camphor, but if agitated with considerable water, it is immediately re-dissolved, and is thus taken internally.

and nitric acids. Nitric acid converts camphor into an acid called the camphoric.

V. USES OF CAMPHOR.—Reviving and refreshing from its odor; stupefies and kills insects, and therefore used to protect animal preparations in museums. Externally used as a discutient; dissolved in acetic acid with some essential oil, it forms the aromatic vinegar; it aids in dissolving copal. Internally, it is a narcotic, antispasmodic stimulant, antiseptic, diaphoretic and diuretic; in ointments, it removes rheumatic pains; used in mania; procures sleep, when nothing else will.

Destructive distillation.—Balls made of 1 part of camphor and 6 of moist clay,* distilled in a retort, yield a volatile oil; camphor is closely assimilated to the volatile oils by being "odorous, pungent, volatile, inflammable, sparingly soluble in water, and abundantly in alcohol;" like them it is wholly unfit for food; it is even dangerous or fatal if taken in too large a quantity, but it is a valuable article of the *materia medica*.

SEC. XIII.—TANNIN.

I. ORIGIN.—The name alludes to the process of tanning, in which this principle is the active agent.

(a.) *Tannin exists in the astringent vegetables*; oak bark, gall nut, willow, chesnut, sumach, &c. and is usually associated with gallic acid.

(b.) *Tannin is found in the bark of most trees.* Terra japonica or catechu, which is the inspissated juice of the *Mimosa catechu*, consists principally of tannin; it is found also in kino and cinchona; in catechu there is 54.5 tannin, 34 extract, 65 mucilage, &c.

II. PROCESSES.†—Berzelius.‡

(a.) *This is complicated but seems to be the best known.*|| In the gall nut, tannin is combined with a little gallic acid; the gall nut contains also compounds of tannin and gallic acid with both these principles united to potassa and lime, besides tannin, in that modified state in which it is called extract; there is likewise a compound of tannin with probably the pectic acid.

Sulphuric acid and potassa are the best reagents for preparing tannin. *To a hot infusion of the gall nut, add a little weak sulphuric acid*; a coagulum of tan and extract is separated by the filter, and to

* That it may not be volatilized before it is decomposed.

† In the original experiment of the discoverer, Seguin, the tannin was precipitated by a solution of animal gelatine; but this is a compound of the two and it will be mentioned again in the history of gelatine.

‡ Ann. de Ch. et de Ph. Vol. XXXVII, p. 385.

|| The general student may pass to c and d, which are more simple.

the filtered fluid add, by degrees and with agitation, sulphuric acid with as much water, till, after the rest of an hour, a semi-fluid glutinous mass appears : decant and add more sulphuric acid to the fluid, till precipitation ceases, and thus a yellowish white compound of the acid and tannin is obtained, which is insoluble in weak acids. Being washed on a filter, with water containing much sulphuric acid, and pressed between folds of unsized paper, it is then dissolved in pure water, which becomes pale yellow ; powdered carbonate of lead, after a little while, removes the sulphuric acid, both the mixed and combined, and the filtered liquor is deep yellow ; the filtered fluid is evaporated to dryness, (best in a vacuum,) and the resulting hard, brownish, yellow mass, contains the tan, mixed with extract. It is pulverized and digested with ether, as long as it dissolves any thing. The ether is evaporated spontaneously, and leaves a transparent mass with a yellowish tinge, unalterable in the air ; and a brown extract insoluble in ether, and not entirely soluble in water, remains.

(b.) *Precipitate a strong infusion of galls, by carbonate of potassa*, not in excess, lest the precipitate should be dissolved ; wash this white matter with ice cold water, and dissolve it in weak acetic acid, which leaves a brown extract formed by the air ; from the filtered solution the tan is thrown down by acetate of lead ; the precipitate, being well washed with water, passes from white to yellow, and is then decomposed by sulphuretted hydrogen. The filtered liquor is colorless, and being evaporated, in a vacuum, with the aid of potassa, leaves the tannin in hard scales, slightly yellow and transparent, and becoming brown by exposure to air and light ; ether dissolves the tannin and leaves the extract. Although the troublesome processes now stated, have superseded those that were before in use, it may be well to mention some of the latter, as general illustrations of the nature of tannin, as it commonly appears, blended with other principles.

(c.) *Add muriate of tin to a decoction of galls*, wash the precipitate, diffuse it in water, precipitate the tin by sulphuretted hydrogen ; the tannin will be dissolved, and on evaporation, will afford a dry, brown, bitter mass, like aloes, which, when re-dissolved, precipitates gelatine.*

(d.) *The sulphuric and muriatic acids*, and the latter especially, promptly *precipitate tannin*† from a strong infusion of galls ; the precipitate is washed in cold, and dissolved in hot water ; the acid is separated by an alkaline carbonate, and washed with cold water ; the residuary tannin may contain extract and gallic acid.

* The tannin thus obtained is much altered in its properties, and is not pure.

† Very well for a class experiment.

(e.) The simplest process is to *precipitate the tannin by lime water*; dissolve out the lime by nitric or muriatic acid, and wash the precipitate with cold water.

(f.) Or, *digest the dry aqueous extract of galls in alcohol*, till it dissolves nothing more; *the residue is tannin*, tolerably pure.*

III. PROPERTIES OF TANNIN.

(a.) *Brittle*, pulverizable, *colorless*; when brown, it is due to the action of the air: astringent; resinous fracture; *cannot be moulded* between the fingers.

(b.) *Not deliquescent*, but *very soluble in water*.

(c.) *Insoluble in pure alcohol*, but soluble in it, e. g. of the sp. gr. .818, when it contains $\frac{1}{8}$ water; *soluble in ether especially if warm*; this fact is remarkable, as being the foundation of the method of obtaining it pure.

(d.) The impure tannin *combines with oxygen*, and a pellicle is thus formed over the infusion of galls; its properties are thus altered, and what is called extract is inspissated in the same manner.

(e.) *The acids*, except the acetic, *throw it down*, from its aqueous solution; the precipitate is soluble in hot water, and falls on cooling; its taste is not acrid but astringent.

(f.) The action of the sulphuric and muriatic acids has been already mentioned.

(g.) *Strong nitric acid decomposes the solution*, which is turbid at first, then of a clear orange color; the diluted acid gives a precipitate.

(h.) *Alkalies and alkaline carbonates partly precipitate and combine with tannin*,† then redissolve it; tannin, while thus combined, has no action on gelatine, till saturated with an acid.

(i.) *Alkaline earths and their carbonates form compounds of sparing solubility*; the precipitate is said to be green.

(j.) *Several neutral salts*, as nitrate of potassa, muriate of baryta, muriate of soda, &c. *precipitate tannin*.

(k.) *Several metallic salts precipitate it*; as acetate of lead, which throws it down gray; nitrate of mercury, yellow; sulphate of manganese, green: &c.

(l.) *Its action on the salts of iron and especially the sulphate, is most peculiar*, and has been explained under iron; with its peroxide, or with a mixture of that and the protoxide, it produces ink and the black dye.

(m.) *Tartar emetic is decomposed by tan* of oak bark, which takes the place of the antimony, and if we use the infusion of galls, the gallic acid forms a gallate of antimony, in fine scales; these effects are

* Thomson, (Edin. Encyc.)

† These compounds are now called tannates, but, as it appears to me, improperly.

probably owing as much to the tannin as to the gallic acid, for the black color is produced by infusion of nut galls, after the gallic acid has been all abstracted.

(n.) *The most characteristic property of tannin is to precipitate gelatine*; this will be mentioned again. One hundred grains of the precipitate contain 54 of gelatine and 46 of tannin.

(o.) *Tannin forms with fecula, a compound*, sparingly soluble in cold but very soluble in hot water; with gluten, an insoluble precipitate.

(p.) *Composition.*—*This is not well understood*, and obviously cannot be, as long as we are not certain that we have yet obtained tannin pure. Berzelius stated its composition as being carbon 50.55, oxygen 45, and hydrogen 4.45; corresponding with 6 equiv. of carbon = 36 + 4 of oxygen = 32 + 3 of hydrogen, 3 = 71; but it is observed, that this does not correspond with the analysis of the compound of tannin and oxide of lead.—*Murray.*

Miscellaneous.—Tannin is found in sumach, bistort, tormentil, rhubarb, squill, whortleberry, several species of pine, the acacias, the seed of grapes, in willow, elm, &c.—*Id.* It is most abundant in the inner bark; in young trees the middle bark contains less, and the epidermis very little. Tannin with gallic acid is found in tea, and in all astringent vegetables.

An infusion of galls, exposed to the air, gradually loses its tannin,* which is apparently converted into gallic acid, the proportion of which is in this manner much increased. Great abundance of tannin exists in hemlock bark, which is much used in this country in tanning; both the wood and the bark of the chesnut† have been used for the same purpose.

Infusion and tincture of galls are constant agents in the hands of the chemist; they afford valuable indications, especially in relation to the metals; it is obvious however, that we do not in these cases employ pure reagents, but compounds and mixtures of several principles.

ARTIFICIAL TANNIN.‡—*Tannin may be formed, artificially, by the action of nitric acid on coal, bitumens and charcoal.* Take 100 grs. of powdered charcoal with 1 oz. of the acid, sp. gr. 1.4 diluted with 2 oz. of water, fresh portions being added as it is dissipated or decomposed; in a few days, a brown solution is obtained, which by evaporation to dryness, gives tannin; 100 grs. of vegetable charcoal produce 114 grs. of this matter. Particular substances give tannin more easily after being charred than before. This is the case even if charred by sul-

* A saturated decoction of galls, on cooling, deposits a copious precipitate of tannin.

† See Am. Jour. Vol. I, p. 312.

‡ See Mr. Hatchett's papers, Phil. Trans. 1805—6.

phuric acid, and this acid itself forms tannin by digestion on resins, balsams, camphor, oil of turpentine, linseed oil, olive oil, and wax; the residuum being washed and digested in alcohol, tanning matter is extracted.

Almost every vegetable substance, even without previous charring, will produce tannin by repeated digestion with nitric acid; it has been thus procured from several gum resins, from the balsams, indigo, &c. Artificial tan is free from gallic acid, and from extract.

For the different varieties of artificial tannin see Mr. Hatchett's papers* and Murray's abstract.†

For the art of tanning see Gelatine; for ink see Iron, and the action of its sulphate on tannin and Gallic acid.

SEC. XIV.—WOOD OR LIGNIN.—WOODY FIBRE.

I. NATURE AND EXTRACTION.

(a.) *It is the basis of wood, the skeleton*, not only of the firm parts, but also of the bark and leaves: after alcohol, water and weak acids and alkalies have been successively applied, to the skeleton, lignin forms 97 per. cent. of its weight.

(b.) *The texture is fibrous*, and the interstices are filled with the peculiar juices and principles of plants, as essential oils, sugar, mucilage, resins, &c.

(c.) To extract all the soluble portions of wood *it must be previously pulverized*, or bruised *and then boiled*, alternately, in alcohol, water,‡ and dilute muriatic acid.§

II. PROPERTIES.

(a.) *Fibrous, white*, partially transparent, *tasteless, inodorous, unalterable* in the air, *insoluble* even in boiling water or alcohol. Sp. gr. 1.48 to 1.52; still, on account of its porousness, it floats.

(b.) *Permanent in a dry air*, but *moisture decomposes it*, with extreme slowness, however, if air be excluded; more rapidly if admitted, carbon being left in the form of a black mould; carbonic acid is formed and oxygen gas is consumed.

(c.) *Fixed alkalies, with heat, soften and partially dissolve and decompose lignin*,|| and become colored and also impart color.

(d.) *Sulphuric acid chars lignin*; if it is mixed and agitated with this acid and water, a black powder falls; the filtered fluid is saturated with carbonate of lime, and a gum similar to gum arabic is obtained.¶

* Phil. Trans. 1805, and 1806.

† Elements and System.

‡ It is very difficult to free wood from extractive matter by maceration in water; indeed it appears to form it by a peculiar action, as some of it can always be obtained by evaporating the water that has acted on wood.

§ To remove the calcareous salts.

|| Cold water dissolves this matter and if the alkali is saturated by an acid, a substance falls resembling ulmin. Ann. Phil. Vol. xvi, p. 92, and H.

¶ H. and Ann. Phil. Vol. xvi, p. 90.

(e.) *Nitric acid turns it yellow*; if in large quantity, it evolves nitrogen, and the wood is converted into oxalic acid with some malic and acetic.

(f.) *Heated* in close vessels it yields various volatile products*; pyroligneous acid† a red pungent liquor, empyreumatic oil, carburetted hydrogen and carbonic acid gas and ammonia, combined with acid; *charcoal remains* of an excellent quality.—Vol. I, p. 356.

(g.) *In the distillation of wood on a large scale, a fluid has been obtained*, resembling alcohol, in some respects, and which is called *pyroxilic spirit*. Its odor is pungent and like that of ether and peppermint; it is colorless and transparent; taste disagreeable; sp. gr. after distillation from muriate of lime, .828 or .812; boils at 150° F.; flame blue; burns without residuum; dissolved by camphor. It is composed of carbon 6 equiv., oxygen 4, hydrogen 7.‡

(h.) Dr. Prout§ states, on the authority of Professor Autenrieth, of Tübingen (who shewed him the fact) that *bread may be made of lignin*. Frequent maceration and boiling remove every thing soluble in water; the wood is then pulverized and repeatedly baked in an oven, and ground, when it smells like corn flour; *it ferments* with a leaven of corn flour and affords a spongy uniform bread with much crust. The flour of wood, by boiling in water, forms a nutritious jelly like that of the wheat starch.||

(i.) *In the open air, lignin burns with flame*, blackens, exhales acrid vapors of acid and oil and burns, leaving a little ashes consisting chiefly of carbonate and sulphate of potassa and lime, muriate of potassa, and phosphate of magnesia and lime, and also portions of earths and metals, particularly iron and manganese.¶—Murray.

(j.) *An ammoniacal salt is always found in the soot of a chimney*, and in the combustion of fuel, water and carbonic acid are formed; from burning wood, arise pyroligneous acid and empyreumatic oil; nitrogen from the air, and charcoal and ashes from the fuel are carried up in the current, and, along with vapor of water, oil and acid, give

* This distillation is performed, in the large way, in preparing charcoal for the manufacture of gun powder: the charcoal is less in bulk than the wood, Vol. I, p. 467.

† See Acetic acid. The pyroligneous acid obtained for the calico printers, &c. is always distilled from wood, unprepared, and therefore may contain all volatile products that are again condensable into the liquid state.

‡ It differs in composition and properties, from the pyro-acetic spirit obtained by Mr. Chenevix by distilling the acetates of manganese, zinc and lead. Ann. Philos. N. S. Vol. VIII. p. 69. Eng. Quart. Jour. Vol. XIV, p. 436. H. and T.

§ Phil. Trans. 1827, p. 381.

|| These facts are highly instructive as shewing the close connexion which subsists between the different vegetable principles, since even wood can be turned into bread.

¶ These products are variable according to the soil in which the wood grew, &c.

the color to the smoke ; gaseous oxide of carbon is also formed, and no doubt varieties of hydrogen and oils are volatilized, in some degree, without being burned ; the color of the soot appears to be derived* from carbon made adhesive to the chimney by the oils of the wood.

(k.) *Composition.*

	Carbon.	Oxygen.	Hydrogen.
100 oak afford	52.53	41.78	5.69
beech	51.45	42.73	5.82†
and this corresponds very nearly with			
Carbon, - - 7 equivalents,	42	53.86	
Oxygen, - - 4 "	32	41.02	
Hydrogen, - - 4 "	4	5.12	
	78	100.	

The results obtained by Dr. Prout corresponded very nearly with the above. The oxygen and hydrogen are in the proportions to form water.

APPENDIX TO LIGNIN.

CORK OR SUBER.

It is not certain that cork is a distinct vegetable principle ; it is perhaps only a variety of the woody fibre, but it has some peculiar properties.

I. ORIGIN.—*It is the bark of an evergreen oak, the Quercus Suber, which grows in the southern parts of Europe, on the Mediterranean. † It is stripped off, every two or three years, in masses of two or three inches thick ; it is scorched, to soften it, and is then pressed flat between two heavy planks, till cold.*

II. PROPERTIES.

(a.) *Light brown or yellow, fine spongy texture ; very soft, but requires keen instruments to cut it ; if dull, they only tear it ; it is highly elastic. Sp. gr. 0.24 ; faint and peculiar aromatic odor, almost tasteless.*

(b.) *Very inflammable ; burns with a large yellow flame, and leaves a bulky soft charcoal.*

(c.) *Water, in a digester, extracted the aromatic principle and some acetic acid, which distilled over ; § while in the water there remain-*

* According to Braconnot, (Ann. de Chim. et de Phys. Vol. xxxi. p. 57 ;) soot is a very complex product ; among the particulars of which, less than 4 pr. ct. of carbon, and carbonaceous matter, insoluble in alkalies, 3.86, are enumerated ; there are 30 of ulmin, 20 of animalized matter, 14.66 of carbonate of lime, water 12.50, acetate of lime 5.65 ; sulphate of lime 5, acetate of potassa 4.10, phosphate of lime with iron 1.56, earths, salts, &c. in small fractions. † Gay-Lussac and Thénard.

‡ I have seen it growing, in Kew Gardens, in England.

§ The digester was of a peculiar construction, having a tube and an adapter with a receiver, and Woulfe's bottles. Chevreul, Ann. de Ch. Vol. xcvi. p. 141.

ed coloring matter; two acids, of which one was the gallic and an astringent gallate of iron.

(d.) 20 parts of cork, thus treated, left 17.15, and after the digestion with alcohol, there remained 14 parts undissolved, and this is what is called suber;* the matters extracted by the alcohol were resin, cerin, and a peculiar oil.

(e.) Cork, acted upon by nitric acid, affords an acid to which the name of the suberic has been given.

If this acid be a peculiar one, which has been alternately admitted and denied,† it appears to possess little interest for the general student.‡ It is white, pulverulent like starch, crystallizable and volatilizable; on burning coals it has the odor of suet; it sublimes in a retort and is condensed again in delicate white needles; nitric acid converts it into oxalic.

(f.) Flax, cotton, hemp and, of course, paper are merely varieties of vegetable fibre or lignin.

SEC. XV.—COLORING MATTER.

Remarks.

1. *Most of the facts, under this head, are interesting chiefly to the arts, and only a few of them are appropriate to elementary chemistry. The art of dyeing depends on chemical principles, but its details cannot be embraced in a work like the present.*

2. *Coloring matter cannot be regarded as a distinct proximate principle; color is a secondary quality of bodies, and may be associated with various principles.*

3. *Still, as innumerable and vivid colors exist among vegetables; as they are soluble in various fluids and can be precipitated and fixed in other substances; are capable of combination with one another, and can be modified, altered and destroyed; it is useful to arrange the prominent facts, and to deduce from them certain general principles. A selection is all that can be attempted, with propriety or advantage.*

4. *We can scarcely say upon what modification of matter vegetable color depends; it evidently does not, as in the mineral kingdom,*

* Mr. Chevreul describes cork, "comme un tissu cellulaire dont les cavités contiennent des matières astringentes, colorantes et résineuses ou huileuses;" this corresponds perfectly with ligneous fibre in which there are foreign principles lodged.

† "Suberic acid is merely gallic acid converted by nitrous acid into oxalic acid, and combined with a little resinous extract, and the suber of Fourcroy consists of vegetable fibre in a very loose state, mixed with resinous and extractive matter, and a little tannin and gallic acid."—*Aikin's Dict.*

‡ See Chevreul's memoirs, Thénard's Chem. &c.

arise chiefly from metals, because metals exist, among vegetables, only in very trifling quantities.*

5. Some of the metals, which produce fine colors in the mineral kingdom, have never been detected in the vegetable, as nickel and chrome.

6. It is not impossible, that *the colors of vegetables may depend upon some peculiar arrangement of vegetable matter* itself, and it is just as probable, a priori, that color should be produced by particular modifications of vegetable, as of mineral matter.

DYEING.†

(a.) *Vegetable coloring matter is usually found with other principles*, in the leaves, flowers, root, bark, stem, fruit, husks, &c. ; it is rendered soluble by various agents, according as it is associated with extractive matter, gum, farina or resin.

(b.) *Instances.* Log wood, Brazil wood, madder, weld, quercitron, turmeric, yield their coloring matter to water; indigo is taken up by sulphuric acid; the coloring matter of lac by alcohol; that of alkanet root by oils, essential or expressed.

(c.) *It is the object of the art of dyeing to take up colors and fix them*, chiefly in wool, silk, linen, hemp or cotton.

PRINCIPLES OF DYEING.‡

(A.) DYEING DEPENDS ON A CHEMICAL AFFINITY between the coloring matter and the fibres of the stuffs, or some bases with which they are impregnated.

(b.) *Generally, wool has the strongest affinity for color*; silk and other animal matters are next, then hemp and flax; but substances which take color the easiest do not always retain it the longest.

(c.) *Those colors which form a permanent union with stuffs, without any intermedium, are called substantive colors.*

(d.) *Others which form only a transient union, a mere stain, removable by washing, are called adjective colors*, because they require the intervention of *some other substance to fix them*: this intermedium is called a mordant or basis.§

(e.) *Alumina, oxide of iron and oxide of tin are the most important mordants* for wool and cotton; alumina and oxide of iron are

* Iron and manganese, which are so extensively concerned in the colors of the mineral kingdom, are however more abundant in vegetables than any other metals.

† Scouring, cleansing and bleaching are usually preliminary to dyeing, for nothing foreign must be allowed to interfere, either with the adherence of the color, or with its proper shade.

‡ For a copious account of the processes of dyeing, see Alkins' Dictionary; also Bancroft's, and Berthollet's, and Cooper's treatises, and a new work by Chevreul, 2 Vols. 8vo., on Chemistry applied to dyeing.

§ Formerly supposed to fix itself by a kind of corrosion, or eating into the stuff: this old idea is however, erroneous, but it gave origin to the word mordant, from *mordeo*, to bite.

used in combination with sulphuric or acetic acid, and tin with muriatic, acetic, or tartaric acid.

(f.) Alum, sugar of lead, copperas, muriate of tin, sulphate of copper, sulphate of zinc, acetate of alumina, acetate of iron, acetate of copper, oxide of arsenic and tannin, are in much request as mordants or bases; but alumina, oxide of iron, and oxide of tin, are the only ones in general use, in dyeing.

(g.) *Alumina, boiled in a colored vegetable infusion, will often combine with the dye, and leave the water colorless.*

(h.) *The same thing happens with metallic oxides*; thus, oxide of copper and oxide of tin detach the coloring matter from logwood and other dye stuffs.

(i.) Metallic salts, dissolved in a colored infusion and decomposed by an alkali, give often a precipitate of the coloring matter with the oxide. See Lakes.

(j.) *The shade and the tint of color are frequently altered by chemical agents*, as acids, alkalies and salts.

(k.) *Light generally weakens vegetable colors*, and chlorine destroys them.

(l.) *There is a great difference in the attraction of coloring matter*, both for stuffs and for mordants.

(m.) *Wool*, in proper proportions, almost entirely *detaches the color from sulphate of indigo*; *silk* does it less perfectly.

(n.) *Cotton is scarcely affected by the bath, which dyes wool scarlet.*

(o.) *Commonly, the base of saline mordants unites with the stuffs and with the coloring matter, and the acid is disengaged.*

(p.) *Hence the reason why, in preparing mordants, acetates are so often formed from sulphates, as acetate of alumina from alum and sugar of lead, or acetate of zinc from the same salt and sulphate of zinc, because, when they are used, the disengaged acetic acid will not injure the stuff.*

(q.) *Mordants not only fix but modify the color*, giving it brilliancy or imparting a particular shade.

(r.) *Thus, alumina changes the dull red of madder to a bright crimson*; tin the crimson of cochineal to scarlet; iron the yellow of weld to olive brown, drab or lead color, according to circumstances.

(s.) *Different mordants are therefore mixed to produce different shades*; thus iron and alumina with madder produce the different shades of "flea color, purple, and violet, with weld, brown, and olive green, &c. so that with three or four colors and various mordants, an immense variety of dyes may be produced."—*Aikins*.

(t.) *In the composition of the dyeing materials there is also a great variety.*

PRINCIPAL COLORS.—*All the colors used in dyeing are reducible to four, namely, BLUE, RED, YELLOW, BLACK.*—*Henry*.

I. BLUE; INDIGO* OR ANIL.—This is the only vegetable substance used in dyeing blue.†

Indigo has so many peculiar properties that it might, without impropriety, be treated of as a distinct principle; it most resembles fecula, but it differs from that and every other vegetable proximate principle.

II. ORIGIN.

(a.) *From three sorts of the indigo plant‡ or Indigofera, viz. tinctoria, agrestis and disperma*; the first is the French indigo, the second is the wild; the third the Gautimala; the tinctoria yields the most, although of an inferior quality.

(b.) *In the West Indies, the seeds are sown in March or April*; the plant flowers in about three months, when it is in perfection and is cut; there are four cuttings in a year; in South America two, in North America one or two; the plants are renewed every year.

III. EXTRACTION.§

(a.) *Steeped in large cisterns under water*; the plants being kept down by plank or a wooden frame; *fermentation soon begins, at the temperature of 80°*, which is the best; carbonic acid and carburetted hydrogen are evolved.

(b.) *Fermentation lasts from 12 to 16 hours*, and it is a critical point when to stop it; if too soon, only a part of the indigo is obtained, if too late it is redissolved; *the proper time is ascertained by trying samples which should, on agitation, precipitate a green pulp*, while a yellow liquor remains above.

(c.) *The turbid liquor is transferred to another vat and briskly agitated for 15 or 20 minutes*, lime is sometimes added; gases are evolved, *and the green pulp becomes blue and subsides*.

(d.) *The water is drawn off and the pulp strained in sacks*; it is then put into square boxes to dry in the shade; but to prevent moulding, it is again heaped in barrels and allowed to remain, three weeks, to undergo a sort of fermentation, after which it is dried in the shade five or six days, when it is finished; thus *indigo is separated by fermentation and agitation, and passes from green to blue, and from a soluble to an insoluble state*.

(e.) Different specimens vary in their qualities according to the mode of preparing, the age and kind of plant, &c.

* Known as a dye very early in India; used as a paint in Europe, but not as a dye, till the middle of the sixteenth century. The Dutch first imported it from India and made its importance known; it was prohibited in England from Elizabeth to Charles II, and also in Saxony, where it was called, in the edict, a corrosive substance and *food for the Devil*; it is cultivated in the West Indies, in Mexico, and in the Southern States and East Indies.—*Thomson*.

† Prussiate of potassa with a salt of iron is much used for dyeing blue, (G. C.) and perhaps iodide of starch might also be employed to advantage.

‡ *The Baptisia tinctoria*, or Bastard indigo of the United States affords a coarser kind of indigo.—*J. T.*

§ See Am. Jour. Vol. XVIII, p. 237, for some instructive facts by W. Patridge.

(f.) *The indigo exists in the plant chiefly as a white matter, which becomes green by exposure to air.*

(g.) Indigo may be obtained from other plants, as the *Nerium tinctorium* and the *Isatis tinctoria* or woad,* but in small quantities.

III. PROPERTIES.

(a.) *Rich blue color, with shades of copper and violet; compact, light,† friable, fracture smooth, tasteless, with hardly any odor.*

(b.) *Impure, from mixture with foreign bodies.* Bergman found in 100 parts, 12 gum, 6 resin, 22 earthy‡ matter, 13 oxide of iron,§ and 47 coloring matter. Hot water, after acting on indigo, exposed to the air, deposits a matter that becomes greenish and then blue, and afterwards a green substance that does not become blue. Alcohol (after the action of water) dissolves a portion of green matter and also of red, and muriatic acid takes up more of the red, and also oxide of iron and earths; the remaining indigo (now purified from every thing but a little silica) is about 45 per cent. of the whole.

(c.) *Insoluble in water, except the mucilaginous part, which is $\frac{1}{10}$ or $\frac{1}{5}$; the color is not taken up; after it has, by losing oxygen, passed to the green state, it is soluble in water.||*

(d.) *Alcohol extracts only some resin, but none of the color; the same of ether; muriatic acid, by removing the earthy and metallic matter, improves its color.*

(e.) *Sulphuric acid is its proper solvent, 1 part of indigo to 8 of concentrated acid; it dissolves in 24 hours and forms a deep black solution; appears blue when a drop is put into a very large quantity of water; this solution is the liquid blue and the Saxon blue; dilute sulphuric acid dissolves only some of the impurities.*

Sulphuric acid, heated with indigo, forms in less than 25 hours, a yellow solution, which in a few hours becomes blue, and instantly, on the addition of water; it is now soluble it that fluid; it is supposed to be modified by the loss of oxygen and hydrogen, and by combination with 4 equivalents of water, and in that state was called by Mr. Crum Cerulin; 1 part of it tinges 500,000 of water sensibly blue; it is precipitated blue by potassa and its sulphate; it resembles tannin in forming insoluble compounds with several neutral salts.

Another compound of indigo 1, and water 2 equivalents, was discovered by Mr. Crum, and called Phenecin, φοινίς, purple, from its producing that color with certain salts, e. g. muriate of potassa.

* Common in Britain, and cultivated in the United States.

† The lighter the better.

‡ Baryta and lime in equal weights, and 1-10 of the whole weight was silica.

§ Bergman is supposed to have exaggerated the iron (by mistake.)

|| Indigo putrefies by being kept long moist.

It is produced after sulphuric acid has acted on indigo 20 minutes at 100° Fah.*

(f.) *Alkaline carbonates throw down a blue powder*, which Bergman called precipitated indigo; this is obtained also by pouring the solution, drop by drop, into alcohol, or into saturated solutions of alum, sulphate of soda, or other sulphuric salts.

(g.) *Sulphate of indigo is changed to green, by sulphurous acid, vinegar, ammonia, alkaline sulphurets, and green† sulphate of iron*, with the addition of lime; a similar effect is produced by weld, madder, sugar and gum.

(h.) *Substances that turn indigo green*, and thus render it soluble, are very numerous; orpiment is commonly used; take a saturated solution of muriate of tin, precipitate the oxide with potassa, and add enough to redissolve the oxide in the alkali; this will cause the blue indigo solution to become instantly green.

(i.) *The green indigo is soluble in alkaline water and lime water, &c.* in which state it is used as a dye; *the cloth comes out green and turns blue* by exposure to the air, owing to a recombination of oxygen, while the change to green is owing to the abstraction of oxygen; it is often disoxygenized by fermentation with bran or other vegetable matter.

(j.) *Indigo, in the blue state, is employed to dye the Saxon blue*; it comes out of the vat blue; the color is however liable to be removed by washing with soap.

(k.) *Indigo dissolves, if mixed with an equal weight of green sulphate of iron and twice its weight of lime*; they are boiled in water;‡ or pure fixed alkali and orpiment are, in preference, mixed with the indigo; sometimes, the ammonia in stale urine is the solvent, and madder and tartar are the disoxygenating substances.

(l.) *In the indigo vats, the green indigo is constantly passing back to blue*; this makes frequent agitation necessary, and sometimes repeated additions of the disoxygenating materials.

(m.) One oz. of *nitric acid*, if strong and fuming, being poured on a dram or two of pulverized indigo, acts violently, and ends in inflammation.

(n.) *If the acid is diluted, it destroys the color and decomposes the indigo*; a yellow solution is obtained, and resinous matter appears which is removed, and we evaporate the fluid to the consistence of honey; it is redissolved in hot water, filtered, and mixed with a

* For additional details see Henry's Chem. 11th Ed. Vol. II. p. 300, and Berzelius, Ann de Ch. et de Ph. Nov. and Dec. 1827.

† Red oxide of iron has no effect.

‡ This forms the dyers' blue vat, and being agitated with air, the indigo is revived, is precipitated considerably purified, and is rendered nearly or quite pure, by digestion with muriatic acid, which (as already observed,) removes iron, and carbonate of lime.

solution of potassa, when yellow crystals appear, which consist of the bitter principle united with potassa; they detonate on an anvil with a purple light; tannin is also formed.

(o.) *Muriatic acid dissolves the iron and earthy matter*; it dissolves however the precipitated indigo and acquires a blue color; phosphoric, acetic, and tartaric acids have a similar effect.

(p.) *Chlorine destroys the color of the indigo solution*, and as the effect is uniform, they are reciprocally tests of each other.

(q.) *Alkalies, alkaline earths and their soluble carbonates have no action upon the coloring matter of indigo*; if however it is disoxygenized and rendered green by any of the processes which have been mentioned, it then dissolves in them and the precipitated indigo is also dissolved by them; the caustic alkalies eventually destroy the color of indigo, but the carbonated do not.

(r.) *A drop of a green solution, placed upon paper, almost instantly turns blue*; when the green solutions are exposed, they absorb oxygen, and the indigo becoming insoluble, falls in a dark blue mud or powder.

(s.) Sulphate of indigo, poured into boiling water, gives a green solution turning into blue.

(t.) Substances, which, like oxide of manganese, abundantly and readily impart oxygen, restore the color to disoxygenized indigo.

(u.) Indigo, if heated in the open air, burns; it detonates with nitre.

(v.) *Pulverized indigo, being thrown upon a shovel, heated below redness, a superb cloud of violet colored matter rises* and partly condenses on the shovel;* it is sublimed indigo; it is attended by an oppressive and lasting odor; the same smell is perceived when blue cloth is heated. This sublimed indigo is more neatly obtained, by heating it by a spirit lamp, about 10 grains at once, in masses weighing each 1 grain, between two slightly concave disks of metal, three inches in diameter, the convex sides being outward and their distance about three eighths of an inch; when a hissing noise ceases, the disks are cooled and the sublimed indigo, in needle crystals of a copper color, is found lining the cover; they are about one fifth part of the weight of the indigo.†

Composition‡ of sublimed indigo, examined by oxide of copper. Carbon 73.22, nitrogen 11.26, oxygen 12.60, hydrogen 2.92 = 100.; corresponding nearly to 16 equiv. of carbon, 96 + 1 of nitrogen, 14 +

* I have attempted, without success, to obtain this sublimate in glass vessels; it always degenerates into a black cloud.

† Crum. Ann. Philos. N. S. Vol. v, p. 81.

‡ The destructive distillation of indigo of commerce, affords 53 per cent. of earthy matter and oxide of iron; the 47 consumed are coloring matter, and afford carbonic acid 2 parts, carbonate of ammonia in solution 8, empyreumatic oil 9, charcoal 23, which, after incineration, left 4, half of which was oxide of iron and half silica; therefore, the coloring matter is composed of hydrogen, nitrogen and much carbon.

2 of oxygen, $16 + 4$ of hydrogen, $4 = 130$.—*Crum.* Mr. Dalton's results vary but little from this, except that he finds the nitrogen 7.7 instead of 11.26.

*Indigo may be obtained colorless,** by digesting 1.5 of it with 2 of green sulphate of iron, 2.5 hydrate of lime and 50 or 60 of water, for 24 hours, the vessel being filled with hydrogen gas, and also the syphon by which it is drawn off; it is then mixed with dilute muriatic acid and sulphate of ammonia, and by good management a white disoxygenized indigo is obtained, which may be dried without becoming blue; it was called by Liebig indigogene; it combines with alkalis and with alcohol; does not turn blue when dry, but becomes blue in a humid atmosphere and under water.† Indigogene, in becoming blue, absorbs 11.5 of oxygen.

Green is produced on woollen cloth, by the green indigo vat, succeeded by simple yellow, varying the proportions, so far as to obtain the desired tint. Silk is first dyed yellow and then blued with indigo.

Saxon green is produced by a yellow upon a Saxon blue ground. Verdigris, dissolved in vinegar, produces a delicate green; pearlash is added before it is used, and cotton, imbued with the alum mordant, is then immersed in the mixture.—*Brande.*

II. RED.—*Archil, Madder, Brazil wood, Safflower, Logwood and the animal color Cochineal,* form the most common red dyes and are all adjective colors.

1. *Archil or Litmus is prepared from a Lichen, the Parmelia Roccella,* growing abundantly in the Canary Islands and South of France,‡ litmus being a compound of the red color of the lichen and an alkali; it is obtained by fermentation, and when an acid engages the alkali, it liberates the color. In the form of litmus or turn-sol, it is much used by the chemists, as a delicate test for acids, and if first reddened, it detects alkalies, by turning back to blue.

2. *Madder; this is the root of the Rubia tinctorum,* and grows abundantly in the South of Europe, in Egypt, and in the Levant, and is cultivated in Zealand in Holland.§ Colin and Robiquet suppose that they have obtained the coloring matter, isolated in brilliant needle crystals, like chromate of lead. Although Madder is a red dye, it may be made, by the aid of proper mordants, to produce all the shades of red, purple and even black, as is seen when calico, stamped with different bases, is immersed in the madder bath.

* Iron or zinc, in diluted sulphate of indigo, changes or destroys the color, in consequence of the evolution of hydrogen.

† Liebig, quoted by Henry.

‡ For the extraction, see Aikins' Dict.

§ Aikins; Eng. Quar. Jour. March, 1829, p. 198; Henry; Ann. de Ch. et de Ph. Vol. xxxiv, p. 225.

3. *Brazil wood is the heart of the *Casalpinia echinata*, a large tree growing in Brazil; with tin and alumina, the tints are lively and agreeable, but not permanent.*

4. *Safflower is the dried flowers of the *Carthamus tinctorius* of Spain and the Levant. Rouge is prepared from this dye, by dissolving the coloring matter in an alkali, and precipitating the color by lemon juice. Two colors are obtained from it, yellow, soluble in water, and the red in the alkalies from which it is precipitated by acids.*

5. *Logwood is a heavy wood from the *Hæmatoxylum Campechianum* of tropical America. Although logwood affords a fine but fugitive red, it is principally used with iron for black.*

*Its coloring matter is called hematine and is obtained in crystals by digesting the aqueous extract in alcohol, and allowing the alcoholic solution to evaporate spontaneously.**

6. *Cochineal is an animal matter, but is mentioned here on account of the color which it affords, which, with water, is crimson and gives only a fugitive dye; but if the solution has tartar dissolved in it, and then per-muriate of tin is added, a fine scarlet is evolved.*

The cochineal insect feeds upon several varieties of the Cactus. Its coloring matter is called carminium or coccinellin. It is separated from fat and from various saline substances by alcohol, which being left to spontaneous evaporation, the coloring matter is redissolved in alcohol, and on mixing it with sulphuric ether, the color is, in a few days, deposited.

III. YELLOW.

Wild American hickory, sumach, turmeric, wild fustic and quercitron are all adjective colors, and various in their hues, according to the bases with which they are combined.

1. *With alumina, quercitron gives a bright yellow, and with oxide of tin all the shades of color, from pale lemon yellow to a deep orange, with oxide of iron a drab, with indigo green.†* It is the rasped bark of the *Quercus tinctoria* or common black oak of the United States.‡

2. *Several species of American walnut or hickory, particularly the *Juglans* or *Carya alba*, afford a yellow dye from their bark,§ and a little iron renders them drab or gray.*

3. The Sumach grows wild in this country and was formerly cut in a mill, packed and exported to England in great quantities.

4. *Turmeric is the root of the *Cucurma longa* of the East Indies: it affords a beautiful yellow, turns brown with alkalies and is used as a test; it is innocent, and is employed to color sugar plumbs yellow, as cochineal colors them red.*

* Ann. de Chim. Vol. LXXXI.

† Henry.

‡ Introduced by Dr. Bancroft.

§ See the experiments of Mr. John Hall, Am. Jour. Vol. III, p. 166.

5. *Weld* is formed from the *Reseda luteola* of *Europe*; with alum it produces a fine yellow, which is rendered more brilliant, by tartar and by per-muriate of tin.

6. *Fustic* is the wood of the *Morus tinctoria*, of the West Indies; with an aluminous base it gives a durable yellow, and is used in forming green and other hues.

7. *Saffron*, from the *Crocus sativus*, gives a bright yellow, with water or alcohol; becomes blue and then lilac by sulphuric acid, and acquires a green tint on the addition of nitric acid. As it produces many colors, it has been proposed to call it *Polycroite*.

8. *Annotta*, from the seeds of the *Bixa orellana*, gives a bright orange yellow with an alkali; it is what is called vulgarly *otter*, and is used to color cheeses yellow; grows in Cayenne.

9. *Butternut*, *Juglans cinerea*, gives a durable brown, upon wood, and with an aluminous basis, upon cotton.

IV. **BLACK.**—Produced, in general, by the decoctions of astringent vegetables with the salts of iron, and particularly the sulphate. Silk requires a larger proportion of galls, and repeated immersion. It is difficult to give cotton a good black; a weak solution of glue aids in retaining the color. The best blacks are first dyed blue, by indigo, and then black. The red maple (*Acer rubrum*) gives a good black with iron and horse chesnut.

V. Several mineral substances have been introduced into dyeing, as Prussian blue, orpiment, chromate of lead, chromate of potassa, &c.

LAKES.

(a.) These are combinations of coloring matter with an earth or metallic oxide, obtained by precipitation.

(b.) The coloring matter of madder is precipitated by alum, especially if aided by an alkali.*

(c.) *Carmin* is the lake of cochineal; it may be precipitated by adding alum, or binoxalate of potassa, to a concentrated solution, obtained by boiling cochineal in water.†

(d.) *Brazil wood* infusion, with alum and an alkali, precipitates the earth and coloring matter.

(e.) The oxide of tungsten is said to afford a more beautiful lake than any other.

(f.) Lakes are much used in water color painting; alum and tin are generally the bases.

APPLICATION OF COLORS IN DYEING.—There are many varieties in the process, but in general, the stuff is passed through a decoction of the coloring matter, and then of the basis or mordant, which, by the double affinity for the fibre and the color, fixes the latter permanently.

* For a very particular process see Henry.

† Pelletier and Cavenou.—Bert. on dyeing.—Partridge on dyeing.

CALICO PRINTING.

(a.) *The mordant or basis thickened with gum, or flour, is applied to the cloth by means of blocks, or engraved copper cylinders.*

(b.) *The cloth is then passed through a decoction of the color, which adheres only to the spots impregnated with the mordant, and is easily discharged from the other parts, by washing, with suitable exposure to air.* Additional colors are printed upon the former ones, by hand blocks, applied with proper mordants, over the other colors. To preserve certain parts white, they are occasionally covered with wax, tallow, pipe clay, or other substances, and sometimes the color is discharged, from particular parts, by chlorine.*

(c.) Acetate of alumina, and acetate of iron are most commonly used as mordants; 3 lbs. alum, 1 lb. acetate of lead and warm water, with 2 oz. potassa and 2 of chalk to neutralize excess of acid.†

SEC. XVI.—VEGETABLE ACIDS.

Under this head, *we include both those which are formed naturally by the powers of vegetable life, and all that are produced by art, by the changes of vegetable matter.*

The number of vegetable acids, of considerable importance, does not exceed ten, while the entire number is from twenty-five to thirty. *Most of them are however, of so little consequence, as to be entitled to only a small space; while the important vegetable acids and their salts will be treated of in sufficient detail.*

1. Vegetable acids (the oxalic acid excepted,) are all composed of oxygen, carbon, and hydrogen, the oxygen being in a greater proportion than is requisite to form water.

2. They are more stable in their composition than any other vegetable principles, being less liable to spontaneous change.

3. Nitric acid, with heat, generally converts them into oxalic acid, and ultimately into carbonic acid and water.

4. Most of them are named from the substances that afford them.‡

I. OXALIC ACID.—NAME.—*From the Oxalis acetosella, a species of sorrel, which affords a salt containing oxalic acid, combined with potassa; this salt is extracted from other species of sorrel, and is probably contained in them all.*

II. DISCOVERY.—*By Mr. Scheele, in Sweden, who extracted it from the salt of sorrel or bin-oxalate of potassa by a process§ no longer practiced, as there are now easier methods.*

* For many particulars see Aikins' Dictionary.

† See Ure's notes to Berthollet's treatise on Dyeing. Thénard's Chemistry, Vol. iv.

‡ The principles of the systematic nomenclature could not be applied to them, as they are of a similar composition, and as they have a double base, the name would have been inconveniently long.

§ Four. Vol. vii, p. 300. One equivalent of acid in the super or oxalate of potassa (salt of sorrel,) is saturated with ammonia, then the oxalate of potassa and

III. PREPARATION.*—*Sugar, 1 part, nitric acid of commerce, 5 or 6 parts of the sp. gr. 1.46 to 1.5, with a gentle heat, in a globe or a tubulated retort of glass, connected with a receiver, to save the excess of acid; red fumes of nitrous gas appear, and when they cease, we add a little nitric acid at intervals, half a part at once, till the action is over.†*

By gentle evaporation and cooling, brilliant crystals of oxalic acid will precipitate, and successive crops may be obtained by repeated evaporations, with a moderate heat. The crystals must all be redissolved, filtered, crystallized anew, and dried on blotting paper.

Obtained also, by the action of nitric acid on molasses, silk, wool, muscles, tendons, hair,|| gums, honey, starch, gluten¶ and alcohol, from most vegetable acids, and from many other bodies, animal and vegetable.

IV. PROPERTIES.

(a.) Commonly described as being in *needle crystals*, flattened prisms of six sides; this is the appearance, but *the real form is that of a modified rhombic prism.*

(b.) *Taste very acid*, setting the teeth on edge; if dissolved and largely diluted, it is agreeably acid; *reddens blue vegetable color* with energy; 1 part of the crystals in 3600 of water, produces this effect; 1 grain of the crystals communicates a sensible acidity to 2633 grains of water; they crackle, when thrown into this fluid.

(c.) *Soluble in two parts of cold and 1 part of hot water*, and in half a part of boiling alcohol; six per cent of the crystals dissolved in cold water, form a liquid of the sp. gr. 1.0314.—H.

(d.) *Efflorescent*; contain nearly half their weight of water of crystallization, but lose only 28 per cent by heat, unless it is pushed so far as to decompose the acid; but if combined with the oxide of lead, its water, amounting to 48 per cent, can all be expelled, and the real acid amounts to 58 per cent.

ammonia is decomposed by nitrate of baryta, the oxalate of baryta is decomposed by sulphuric acid, and the oxalic acid is obtained in crystals, by evaporating the liquor; for a process, by acetate of lead and sulphuric acid, see Thénard's Chem. Vol. III, p. 629.

* The process by sugar was discovered by Bergman.

† If too much acid be used the product will be diminished, and the oxalic acid may even be all decomposed.

§ In London (July 10th, 1805,) from $\frac{1}{2}$ lb. of white sugar with $3\frac{1}{2}$ lbs. of aqua fortis, I obtained $4\frac{1}{2}$ oz. of oxalic acid, which cost (for the materials only,) 2 shillings sterling per oz.; the present price in New York is \$1 50 per lb. Oxalic acid is now made, in some oil of vitriol manufactories, from molasses, to which nitric acid is added, for the purpose of generating nitric oxide gas, to be conducted into the leaden chamber where the sulphur is burned, and where by absorbing the oxygen of the air, and thus forming nitrous acid vapor, it will aid in converting the sulphurous acid gas into sulphuric acid. See Vol. i. p. 308 and 466. The residuum of this process is converted into oxalic acid.—O. C.

¶ Fourcroy, vol. ix. p. 69.

|| The process by starch is one of the best; see the conclusion of this article.

(e.) *Composition.*—The crystals contain four equivalents of water, 36, with one equivalent of acid, 36, and the representative number is therefore 72.

Formerly, this acid was supposed to consist of oxygen, carbon and hydrogen,* but the most recent results give carbon and oxygen only.

Carbon,	33.34	2 equiv.	12
Oxygen,	66.66	3 “	24

100.

36 its equivalent.†

It is singular, that this powerful acid in firm crystals, should be midway in composition between the two gases, carbonic acid and carbonic oxide, and it may even be regarded as composed of 1 equiv. of carbonic acid, 22, and 1 of carbonic oxide, 14, = 36, containing, obviously, the same amount of carbon and of oxygen. It has the composition of a mineral acid, and it has been proposed to call it the carbonous acid, which its composition would fully justify.

(f.) *Oxalic acid, in a dose of some drachms, acts as a poison*, and has been repeatedly taken by mistake, for Epsom salt, which, to the eye, it considerably resembles, but it is instantly distinguished by the taste alone,§ which is intensely acid, while that of Epsom salts is equally bitter; oxalic acid also precipitates lime water, and the precipitate is not redissolved by more acid.|| Copious draughts of warm water, containing bi-carbonate of potassa or soda, or chalk and magnesia, are effectual remedies for this poison; emetics should also be given.

V. *USES.*—Oxalic acid, in fine crystals, is now sold in the shops; its principal use is in cleaning brass, and other metallic articles, and in whitening boot tops, in preparing printed goods, &c.; it is sold in England, under the very improper name of salts; the acid of the salt of sorrel is used to remove iron stains.

Remarks.—The agreeable sub-acid taste of the common sorrel, *Rumex acetosa*, is owing to the acid of the bin-oxalate of potassa which it contains. Several species of the crustaceous lichens¶ contain the oxalate of lime, equal to half their weight, and it is to them what the carbonate of lime is to corallines, and phosphate of lime to bones, (Braconnot.) Oxalic acid and oxalates exist in many vegetables.

* Fourcroy gave its composition at 77 oxygen, 13 carbon, and 10 hydrogen.

† Thomson, Ure, Berzelius.

§ The mistake on the part of an apothecary is unpardonable; the ox. which is safe, if it be Epsom salts, is fatal if it be oxalic acid; 2 or 3 drachms of it will kill.

|| It is the only vegetable acid that, uncombined, precipitates lime, “ Il précipite toutes les dissolutions calcaires: c'est le seul acide végétal qui ait cette propriété;” O-L. Cours, &c.; several do it by double affinity.

¶ Found in all parts of North America.

Oxalic acid is found, free, in the juice of the fibres or hair of chick pease;* it exudes, when they are cut by scissors, and persons who walk over a field of chick pease, have their shoes burned by this acid.

IV. *Miscellaneous*.—When† carbonic acid and carbonic oxide are produced, by heating oxalic acid or the bin-oxalate of potassa, with sulphuric acid, the carbonic acid is removed by lime water or potassa, and the carbonic oxide remains; the sulphuric acid is not decomposed and appears to operate by removing water, and the elements of the oxalic acid arrange themselves anew.

Oxalic acid and the oxalates, boiled with a solution of gold, reduce the oxide, and produce carbonic acid.

The greater part of the oxalic acid used in the arts, in the manufacture of printed goods, is obtained by the action of nitric acid upon sugar or starch; with starch 1 part, and nitric acid 6, added at intervals and aided by heat, they obtain more than half the weight of the starch in oxalic acid.‡ Oxalic acid takes lime from every acid, even the sulphuric and the phosphoric.§

OXALATES.

1. Composed of oxalic acid and bases; most of them unimportant.
2. *Generally insoluble, or sparingly soluble* in water; soluble in nitric and in muriatic acid.||
3. The oxalates of potassa, soda, lithia, alumina and iron are the most soluble.¶
4. From a soluble oxalate, a neutral salt of lime or of lead throws down an insoluble oxalate, which is decomposed by sulphuric acid, forming an insoluble sulphate, and crystals of oxalic acid are obtained on cooling.
5. All insoluble oxalates, the bases of which form insoluble compounds with sulphuric acid, may be decomposed in a similar manner, and all other insoluble oxalates, by potassa, and soluble oxalates formed.
6. *Decomposed at ignition*; no charcoal is left, being burned by the oxygen of the acid, and a carbonate remains, if the base can retain carbonic acid, or if the heat be pushed, the base alone remains, (ammonia excepted.)
7. *Some oxalates are metallized by ignition*, emitting pure carbonic acid; the 1 equivalent in the neutral protoxide being transferred to the oxalic acid, to form carbonic acid.**
8. *Decomposed by hot sulphuric acid*, generating carbonic acid and carbonic oxide.

* Fourcroy, Vol. vii, p. 302. Chaptal, Vol. iii, p. 115.

† Ann de Ch. et de Ph. Vol. xix, p. 84; see also this work, Vol. i, p. 396, (g.)

‡ Laugier's Cours, &c. Vol. iii, p. 211. § Except, perhaps, the fluoric.

|| Except where the latter precipitates the bases of the salts.

¶ An additional equivalent of acid does not render the alkaline oxalates more, but less soluble, contrary to the general state of facts among saline bodies.

** Gay-Lussac, Turner.

I. BIN-OXALATE OF POTASSA, or salt of sorrel of the shops.

I. ORIGIN.—Already stated to be found native in the sorrels, and in many other vegetables; that of commerce comes chiefly from Switzerland; it is very white, and is extracted from the *Rumex acetosella*, gathered in June; that of Thuringia is yellowish and is from the *Oxalis acetosella*. The plants are repeatedly bruised, macerated and pressed, and from the fluid, crystals are obtained by evaporation. It is easily formed synthetically.

II. PROPERTIES.

(a.) Taste acid and bitter; soluble at 60° in 10 parts of water, and in less at 212° ; crystals rhomboidal parallelopipeds, resembling cubes; reddens vegetable blues.

(b.) Composition.—Acid 2 equiv. 72 + alkali one, 48 + water two 18 = 138 its equivalent.

(c.) It is used to remove iron and ink stains, which it does by transferring 1 equivalent of the acid to the iron, thus forming a soluble oxalate of iron and leaving a soluble oxalate of potassa.*

II. OXALATE OF POTASSA.

I. Preparation, by saturating oxalic acid or the bin-oxalate with potassa or its carbonate.

II. PROPERTIES.

(a.) The crystals are oblique prisms of four sides; taste bitter and cool; soluble at 60° , in 2 parts of water.

(b.) Composition, acid 1 equiv. 36 + 1 equiv. of potassa, 48 + 1 of water, 9 = 93 its equiv. Much used as a test for lime, with which it forms an insoluble precipitate, provided there is no free mineral acid in the water, which would redissolve the precipitate. It is remarkable, that the oxalate is much more soluble than the bin-oxalate, contrary to the general analogy of salts.

III. QUADROXALATE OF POTASSA.

I. PREPARATION.—By digesting the bin-oxalate with nitric or muriatic acid, which takes half the base and leaves the other half, combined with the whole of the acid, and of course with four equivalents.

II. PROPERTIES.

(a.) Forms beautiful crystals, which are obtained pure by a second crystallization.

(b.) The alkali, remaining from the decomposition of 3 parts of this salt, by heat, exactly saturates the acid in one part of the crystals.

(c.) Hence, it contains 4 equivalents of acid = 144 + one of alkali 48 + 7 of water, = 63 = 255 its equivalent. We owe this beautiful proof of the truth of the law of multiple proportions to Dr. Wollaston.†

* Aromatized, by oil of lemons, it is used as an acidulous drink in some diseases; it is antiseptic, and will preserve meat.

† Phil. Trans, 1806, p. 99. See also Beqard, Ann. de Chim. Vol. LXXIII, p. 371.

	Equiv. of base.	Equiv. of acid.	Base.		Acid.	Equiv.
Oxalate contains	1	+	1 = 48	+	36	= 84
Bin-oxalate,	1	+	2 = 48	+	72	= 120
Quadroxalate,	1	+	4 = 48	+	144	= 192 (E.)

IV. OXALATE OF SODA.

(a.) *Formed synthetically.*(b.) *Composition.*—Base 1 equiv. 32 + 1 of acid, 36 = 68 its equivalent;* 100 of soda require 112.5 acid, and as it forms a bin-oxalate, twice as much acid = 225 parts are required in that salt; 1 equiv. base = 32 + 2 of acid = 72 = 104, its equiv.; there is no quadroxalate.

V. OXALATE OF AMMONIA.

(a.) *Formed synthetically.*(b.) *Crystallizes in long transparent prisms; taste bitter.*

(c.) Soluble at 60° in the ratio of 45 grains to 1000 of water; in hot water very soluble, and a saturated solution, on cooling, deposits crystals.

(d.) *Composition.*—Ammonia 1 equiv. 17 + 1 of acid, 36 = 53 the equivalent of the anhydrous salt, and in the crystals there are 2 equiv. of water 18 = 71; there is a bin-oxalate, not so soluble as the oxalate. It is a very useful reagent, especially in detecting lime, and is preferred to oxalic acid, because the latter, by setting free a mineral acid, might cause the resolution of the oxalate of lime, while the acid would be engaged by the ammonia, if the oxalate of that base were used.

VI. OXALATE OF LIME.

(a.) *Formed, between oxalic acid or any soluble oxalate, and lime water, or any soluble calcareous salt; turns syrup of violets green.*(b.) *It is a white powder, insoluble in water, but, when recently precipitated, it is very soluble in nitric and muriatic acids; if, in any water, which we could examine for lime, by means of oxalic acid or a soluble oxalate, nitric or muriatic acid is present in a free state, they must be neutralized before the application of the test; thus, oxalic acid and lime become tests of each other's presence.*(c.) *Decomposed by carbonate of potassa.*(d.) *Composition.*—Lime 1 equiv. 28 + acid 1 equiv. 36 = 64 the equiv. of the salt; per cent. lime 43.75 + acid 56.25 = 100.*If slowly dried, it retains four, if rapidly, six equivalents of water, and it is anhydrous, after being heated to 560° F. which temperature it sustains without decomposition. There is no bin-oxalate. This salt is the basis of the mulberry calculus.*

VII. OXALATE OF BARYTA AND OXALATE OF STRONTIA have nothing interesting, except that the bin-oxalate of baryta is soluble, while the

* The water, contained in the crystals, is not in equivalent proportion and is neglected.

oxalate is nearly insoluble; the latter is converted into the former, by the addition of acid, and its crystals are decomposed, by mere solution in water.

VIII. *OXALATE OF MAGNESIA, formed by mingling sulphate of magnesia and oxalate of ammonia*; if the sulphate has been moderately diluted, with cold water, it is not precipitated until it is heated, although after it has fallen, it is insoluble; as lime is instantly precipitated, this affords the best method known of separating these earths. Among the metallic oxalates, some, as those of nickel and cobalt, afford a pure metal, by ignition.

IX. *The oxalate of lead, formed by oxalic acid and acetate or nitrate of the metal, detonates, by being heated in a tube with bits of potassium.**

X. *The oxalate of mercury, produced in the same manner, detonates by heat, and was formerly supposed to enter into the constitution of Howard's fulminating mercury.* Oxalate or bin-oxalate of potassa and antimony, heated together in a covered crucible, afford an alloy of potassium and antimony. Per-oxalate of copper, digested with oxalate of ammonia, affords crystals that detonate by a sudden heat.

II. TARTARIC ACID.

I. NAME AND HISTORY.

Name, from the crude tartar of wine, or from the salt that is purified from it, (cream of tartar,) from which this acid is extracted. Discovered by Scheele in 1770.† It exists in several acidulous fruits‡ but always in combination with lime or potassa. *We always extract it from combination*; it is never formed synthetically.

II. *PROCESS,|| by decomposing the bitartrate of potassa, by chalk.* Taking the proportions by the equivalents, they are as follows.§

* H. and Phil. Mag. 1827.

† His first recorded discovery.

‡ Found in the tamarind, in balm, *Carduus benedictus*, roots of resharrow, germander and sage; sumach is quoted in foreign books as containing tartaric acid, but I am reminded by Prof. Tully, that the American *Rhus glabra* affords malic acid, and that this is probably the fact with all the other American acidulous sumachs. —Ann. Lyc. N. York, Vol. 1, p. 42.—I. Cozzens.

|| Or, 100 parts of cream of tartar, 26 1-2 to 30 chalk in 8 or 10 times as much water; add the chalk by portions, when the effervescence ceases, add to the clear liquor a solution of nitrate or muriate of lime, so long as a precipitate falls, wash it and then double as much sulphuric acid as chalk must be added to the tartrate of lime diffused in water, and after 24 hours, the liquor may be examined for sulphuric acid by adding acetate of lead; if the precipitate is only tartrate of lead it will be entirely soluble in diluted nitric acid; if any thing remains, it is sulphate of lead, indicating an excess of sulphuric acid which may be saturated by more chalk, or if the tartrate of lime has not all been decomposed, more sulphuric acid may be added. A little excess of sulphuric acid does no harm, but much would decompose the tartaric acid.

Dr. Henry thinks, that no advantage is gained by substituting quick lime for chalk, for although more of the cream of tartar is decomposed, the liberated potassa dissolves the tartrate of lime and thus prevents its precipitation. With chalk we remove only one equivalent of tartaric acid.—Henry and A. A. Hayes. § Turner.

Powder of cream of tartar (bitartrate of potassa) 198 parts, or one equivalent, intimately mixed with 50, or one equiv. of chalk; throw the mixture, by portions, into 10 parts of boiling water; carbonic acid escapes, with effervescence, and 1 equiv. of tartrate of lime falls, and one of soluble tartrate of potassa remains in solution;* the precipitate is washed, and then diffused through a moderate portion of water, containing one equiv. of sulphuric acid, 49; digestion liberates the tartaric acid, and after the separation of the sulphate of lime by the filter and due evaporation, the acid is obtained in crystals.

III. PROPERTIES.

(a.) *Taste very acid*, setting the teeth on edge, but when diluted, it is agreeable; *reddens the vegetable blues*.

(b.) *Crystallizes in tables or prisms*;† primitive form a right rhombic prism; sp. gr. 1.59.

(c.) *Soluble in 5 or 6 parts of water at 60°*, and in much less of boiling water, a saturated solution, sp. gr. 1.230, becomes mouldy on the surface by keeping; soluble in alcohol.

(d.) By strong nitric acid, converted into oxalic.

(e.) *Does not precipitate lime from the mineral acids*, but separates it from the vegetable; it precipitates baryta and strontia.

(f.) *Composition*.—By the researches of the most distinguished analysts, it appears, that *this acid contains about two thirds of its weight of oxygen; from one quarter to one third of carbon, and a small portion of hydrogen*. Dr. Henry gives, as the most probable constitution,

Carbon	4 equiv.	24	36.36
Oxygen	5 “	40	60.61
Hydrogen	2 “	—	23.03

66 100.—And the crystals consist of anhydrous acid 1 equiv. 66 + 1 water 9 = 75; per cent. 88.16 acid + 11.84 water.‡

(g.) *Destructive distillation gives pyro-tartaric acid§ besides the usual products* of much inflammable and other gases, and charcoal remains. *The acid rises in sublimation* and is also dissolved in the fluid; it affords crystals, which, by heat, give a white sublimate; its distinct character has been both admitted and denied, and is now admitted again.

* It may be decomposed by muriate of lime and the insoluble tartrate of lime, by sulphuric acid, as before, or it may be reserved as tartrate of potassa for other purposes.

† The appearance of the crystals is often confused; in plates, needles, leaves, pyramids, prisms, groups, &c.

‡ Prout, Phil. Trans. 1827.—Thomson's First Principles, II, 115.

§ This has been supposed to be the acetic, disguised by oil; it differs from the tartaric in the compounds it forms; it does not precipitate baryta or lime, or form a salt of sparing solubility with potassa.

IV. USES.—*The tartaric acid is so intensely sour, as to require large dilution with water, when taken as a beverage.*

It is given in the military hospitals as a cooling drink, and its use in soda powders has been already stated. It is free from the rough taste of cream of tartar, and is one of the most agreeable and permanent of the vegetable acids; its crystals undergo no change by weather, climate or time.*

It is now largely manufactured and sold in the shops, under the name of tartaric acid, and is an agreeable substitute for lemonade.

TARTRATES.

1. The tartrates consist of tartaric acid, and a base, which, when they are decomposed by heat, is generally left, mixed with charcoal.

2. The bi-tartrates are less soluble than the tartrates, in this respect resembling the oxalates; the earthy tartrates are generally insoluble, and are obtained by double decomposition.

3. All the soluble tartrates form bi-tartrates of sparing solubility, while the insoluble tartrates may be dissolved, in an excess of their own acid.

4. The tartaric acid is prone to unite with two bases, at once, to form double salts.

I. BI-TARTRATE OF POTASSA.—Cream of tartar.

I. ORIGIN.—*Exists in many vegetables and fruits,† and is produced by the fermentation of the juice of grapes, especially those affording the red and Rhenish wines; the salt, as it forms during the fermentation, is deposited on the interior of the wine casks,‡ and from this substance, called tartar, or crude, or wine tartar, or argal, the cream of tartar, bi-tartrate of potassa, is prepared.§*

The process consists, as in the case of bin-oxalate of potassa, in solutions, filtrations and crystallizations, clay or whites of eggs being used, to clarify the fluid. *The crust of crystals, that appears on the surface, being skimmed like cream, and hence the origin of the appellation, cream of tartar.*

II. PROPERTIES.

(a.) *Crystals, irregular six sided prisms|| with six terminating faces; the primary form, a right prism rectangular or rhombic. Sp. gr. 1.953.*

(b.) *Taste, acid and rough; brittle; reddens the vegetable blues.*

* Vol. i, p. 383.

† It is abundant in the tamarind.

‡ It is knocked off and sold under the name of wine stone; it often contains or copies the fibres of the cask, and is colored more or less deeply by the wine.

§ Rozier, Jour. de Ph. Vol. i, p. 67.—Memoires de la Academie, 1725, and Fourcroy, Vol. vii, p. 319.

|| For a more exact account of their form, see Thomson's Annals, Vol. x, p. 37, and N. S. Vol. vii, p. 161.

(c.) *Soluble in 60 parts of water at 60° F., and in 14 at 212°; hence, it crystallizes very rapidly by cooling, but falls rather in grains than distinct crystals.*

(d.) *Composition.*—It appears to consist of

Acid, 2 equiv.	132	73.69 per cent.
Potassa, 1 “	48	26.11
	180	100.

To the number 180, we must add the water in its crystals, 1* equiv. or 2†; it cannot be separated without decomposing the acid.

That it contains 2 equiv. of acid is proved by the fact, that the alkali which remains from the incineration of a given weight, precisely saturates the same weight of the crystals, dissolved in water.

(e.) *Destructive distillation, besides a great volume of gases and empyreumatic acid and oil, affords in the residuum, carbonate of potassa‡ about one third of the weight, formerly called, on account of its origin, salt of tartar; it is generally regarded as pure,§ but a little lime and silica, and a trace of alumina, iron and manganese have been observed.||*

III. *Uses.*—*A mild and valuable medicine; ¶ with oxide of antimony forms tartar emetic,** affords tartaric acid and soluble tartar, †† and black and white flux; ‡‡ it appears to be concerned in giving the peculiar roughness to the red wines. It is used in dyeing, felting, gilding, domestic processes, &c.*

II. TARTRATE OF POTASSA.—*Soluble tartar.*

I. *ORIGIN.*—*Found in the juice of ripe grapes, and other pulpy fruits; most abundant in the red grape.*

II. *PROCESS.*

(a.) *By saturating the solution of the super or bi-tartrate, by carbonate of potassa; it is always thus formed, in the first step for obtaining tartaric acid.*

(b.) *By saturating tartaric acid§§ in the same manner till, in both cases, effervescence ceases.*

III. *PROPERTIES.*

(a.) *Very soluble and even deliquescent; decomposed by most acids, bi-tartrate of potassa being deposited; during the fermentation of wines, it is decomposed by the carbonic acid, which takes one half its base, and most of the bi-salt then falls.*

* Thomson.

† Berzelius.

‡ Mixed with charcoal, which is removed by solution and filtration.

§ Especially free from soda, and was therefore used, by Gay-Lussac and Thénard in preparing pure potassium. ¶ Ann. de Ch. Vol. LXIV, p. 48.

¶ Dose half an oz. to 1 oz. and less as an aperient or alternative.

** See p. 212 of this Volume.

†† See those articles.

‡‡ Vol. I, p. 470.

§§ 112 of acid to 120 of sub-carbonate and 100 of cream of tartar to 431.2 of sub-carbonate.—H.

(b.) *Crystals*, often irregular six sided *prisms*, with dihedral summits; primitive form, a right rhomboidal prism.

(c.) *Composition*.—Acid 1 equiv. 66 + 1 potassa 48 = 114, and in the crystals, 2 equiv. of water 18 = 132; a heat of 248° F. expels the water without decomposing the acid; per cent. the anhydrous salt contains acid 57.90 + potassa 42.10.

IV. *USES*.—*Chiefly medical*; it is the soluble tartar of the physician, and is frequently formed in the first mode named above.

Remark.—Such is the tendency of tartaric acid to form an insoluble bi-tartrate, with potassa, that it takes that alkali even from the mineral acids—e. g. from the muriate of potassa, and when tartaric acid is added to a solution of tartrate of potassa, a white powder falls, which is the bi-tartrate. If to a strong solution of tartaric acid, we add half enough of potassa to saturate the acid, there will be a precipitate of bi-tartrate; if as much more alkali is added, it will be redissolved and the precipitate will be renewed on adding an acid, e. g. the muriatic.

3. TARTRATE OF POTASSA AND SODA.—*Salt of Seignette,* Rochelle salt.**

I. PROCESS.

(a.) *By saturating cream of tartar*, 18 parts, with *sub-carbonate of soda*, 18.

II. PROPERTIES.

(a.) *The crystals are often large and very beautiful*; form prismatic, or rhomboidal prisms, with 10 or 12 sides.

(b.) *Soluble in 5 parts of cold*, and in much less of boiling water; taste, bitter.

(c.) *Composition*.—Tartrate of potassa 54 + tartrate of soda 46, which are almost exactly the equivalent proportions.

III. USES.—*A valuable medicine.*

The cream of tartar is so prone to combine with an additional base, that it often acts as a simple acid, and dissolves oxides that are insoluble in the mineral acids, and even in the tartaric.†

4. TARTRATE OF SODA.—It has been already mentioned, as being formed, when the soda powders are mixed; carbonate of soda is better adapted than carbonate of potassa to that use, because it is less prone to form an insoluble bi-salt. The crystals of tartrate of soda are fine needles.

5. TARTRATE OF AMMONIA is formed synthetically; bitter, very soluble; forms an insoluble bi-tartrate.

6. EARTHY TARTRATES.—The tartrate of lime is produced, as already mentioned, in the process for tartaric acid; it has no other use.

* From the apothecary by whom, and the place at which, this salt was first formed.
† Ann. de Ch. et de Ph. Vol. III, p. 281, and H.

The other earthy tartrates are formed, in general, by double exchange, between the tartrate of potassa and a soluble salt of the earth.

7. METALLIC TARTRATES.—That of antimony and potassa is the only important one, (see antimony p. 212.)

The tartrate of lead, formed between acetate of lead and tartaric acid or tartrate of potassa, is a white powder, and when warmed in a tube and poured out into the air it is a *pyrophorus*.

Tartrate of mercury is an insoluble white powder; a triple compound is formed between 6 parts of cream of tartar and 1 oxide of mercury by boiling.

III. CITRIC ACID.

I. NAME, from *Citrus*, the lemon or orange, which contains it in abundance; *discovered by Mr. Scheele*, of Sweden.

II. PROCESS.*

(a.) *Lime or lemon juice is neutralized by chalk, and the citrate of lime is decomposed by sulphuric acid.*

(b.) Saturate the expressed juice by powdered chalk,† with agitation; after subsidence of the solid citrate of lime decant the water, add more, repeatedly, till there is no taste or color in the fluid.

(c.) To the solid citrate,‡ constantly stirred, add as much sulphuric acid, of a density not far from 1.85, diluted with 10 parts of water; stir the mixture, occasionally, for 24 hours; let the sulphate of lime subside; add water, till it comes off tasteless; mix the liquors,§ and evaporate to $\frac{1}{2}$, and more sulphate of lime will fall; evaporate again to the density of a syrup, and brown crystals will form, which are purified by repeated solutions and crystallizations.

III. PROPERTIES.

(a.) *Crystallizes in large rhomboidal tables* or prisms; transparent and beautiful; primitive form, a right rhombic prism.

* As citric acid has become an important article of commerce, much attention is now paid to the details of the manufacture, a full account of which may be found in Parkes' Chemical Essays, and in the 46th Vol. of the Phil. Mag. See also Henry's Chem. 11th edition, Vol. II, p. 228.

† According to Dr. Henry's experience, 6 or 8 oz. of chalk will saturate a wine gallon of lemon juice, and in 1 gallon, he has found even 12 oz. of solid citric acid, but it averages about 6 or 8 oz. to 1 gallon; for a method of estimating the proportion with sufficient accuracy, see Henry's Chem. Vol. II, p. 229, 11th edition.

‡ The equivalents are dry citrate of lime, 86, + 49 of strong sulphuric acid diluted with 10 of water. In general, 90 parts of lemon juice (94 Proust,) require 4 parts of chalk for saturation, which produce 6 parts, (7 1-2 Proust,) of citrate of lime, and 18 parts (20 Proust,) of sulphuric acid are necessary for their decomposition.

§ They may contain a little sulphuric acid and mucilage; the former is detected by acetate of lead, and may be neutralized by more citrate of lime; but a little does no harm, as the citric acid crystallizes and leaves the sulphuric, and also the mucilage. If there is lime in excess, the citric acid will not crystallize.

(b.) *Crystals, permanent* in the air*; lose about 7 pr. ct. by being heated, to the point just below decomposition; *endure all climates and vicissitudes of weather, unchanged*, but the aqueous solution, like those of most vegetable bodies, is slowly decomposed by keeping.

(c.) *Taste very acid*, but agreeable, and *not corrosive*; in solution *with water*, it is *grateful*; *reddens the vegetable blues*; soluble in $1\frac{1}{2}$ part of cold water, and in half its weight of boiling water.

(d.) *Nitric acid*, 3 parts, *converts it into the oxalic*, half a part, and by increasing the proportion of the nitric, it is essentially converted into the acetic acid.

(e.) *Composition*.—The most eminent chemists have obtained different proportions; but the most probable constitution, deduced from the experiments of Thomson and Berzelius, appears to be, carbon 4 equiv. = 24, and oxygen 4 = 32, hydrogen 2 = 58, the equiv. of the acid.†

(f.) *Destructive distillation affords the usual products of vegetable decomposition, and also an acid*, supposed to be a peculiar one; it is called the *pyro-citric*, but if a distinct acid, it is not important.‡

IV. *USES*.—*Tartaric acid is carried to sea as an antidote to scurvy*; it affords an excellent substitute for lemonade; it is necessary only to dissolve it in about 19 parts of water with sufficient sugar, and add the essential oil of lemons. It may be mixed, in the proportion of half an ounce with one pound of sugar, and this may be essenced by 5 or 6 drops of oil of lemons on a lump of sugar.

It was, many years ago, suggested by Fourcroy, that the juice of limes and lemons might, in the West Indies, be saturated with lime or chalk, and then exported to Europe for decomposition by sulphuric acid; this is now done with advantage.

Citric acid is often employed in making the effervescing mixture, with carbonate of potassa or soda. It removes iron stains in the same manner as oxalic acid. It is used by dyers, to enliven the color of the safflower, and to produce a fine red with tin and cochineal, especially for silk and morocco. Like tartaric acid, it whitens and hardens tallow. As the tartaric acid is cheaper than the citric, it is sometimes used to adulterate it, and may be discovered, by adding carbonate of potassa, which, if tartaric acid be present, will precipitate cream of tartar.

* I have one nearly an inch square, formed in London, (July 1805,) which remains unchanged after twenty five years; the acid in the entire solution, placed in Mr. Accum's garret and forgotten, was found to have been absorbed into a single crystal, doubtless at the expense of many smaller ones, in the manner pointed out by Dr. Wollaston, (Faraday's Chem. Manip. p. 253.) In general, great quantities of fluids are necessary to produce large and fine crystals, according to the method of Mr. Dizé in Paris.

† For different views, see Henry, 11th edition, Vol. 11, p. 231, and Phil. Trans. 1812; also Gray's Operative Chemist.

‡ See Henry, Vol. 11, p. 233.

CITRATES.—Formed synthetically, but they are *little known*, and are at present *not interesting*. In general, with the exception of the citrate of zinc,* they form gummy masses and do not crystallize.

Citric acid precipitates barytic but not lime water, unless the latter is in excess, and fully saturated in the cold. Citrates, soluble in water, are those of the alkalies, magnesia and iron; insoluble, or sparingly soluble, those of the other alkaline earths, and of lead, mercury and silver, but more of their own acid dissolves them, and they are decomposed by sulphuric acid.

IV. MALIC ACID.

I. NAME, &c. from *Malum*, the apple, in which it is found; it exists also in the currant, the strawberry, blackberry, cherry, raspberry, barberry, plum, hawthorn, houseleek, tamarind, berries of the service tree, &c.

II. DISCOVERY.—By Scheele, in Sweden, in 1785.

III. PROCESSES.†

(a.) The juice of the unripe berries of the service tree (*Sorbus aucuparia*) affords malic acid by a very complicated and troublesome process.‡

(b.) The following, on the same plan, is more concise. *The juice of the unripe berries of the service tree or mountain ash, diluted with 3 or 4 parts of water is filtered and heated, boiling hot, and acetate of lead is added, as long as it is turbid; the malate of lead is dissolved and*

* Citrate of soda crystallizes in six sided prisms.—Ure.

† 1. *By digesting sugar with its weight of weak nitric acid; this is the same process as that for oxalic acid, but with less nitric acid; oxalic acid is also formed and may be saturated by lime water, with which it precipitates; more lime or chalk is added to saturate the malic acid and form a soluble malate of lime, which is coagulated by alcohol. It is again dissolved in water, decomposed by acetate of lead, to form an insoluble acetate of lead and then the malic acid is separated by the sulphuric, which unites with the water. This process is complicated and often fails, at least in my experience.*

2. *The juice of sour apples, gooseberries and other fruits, containing citric and tartaric and sometimes other acids, is reduced greatly by evaporation; alcohol coagulates the mucilage and dissolves the acids; chalk neutralizes them, and hot water dissolves the malate of lime and leaves the citrate, which is insoluble; sulphuric acid then decomposes the dissolved malate of lime.*

3. *The juice of sour apples is neutralized by carbonate of potassa, decomposed by acetate of lead, the insoluble malate of lead is also decomposed by diluted sulphuric acid, separated from the sulphate of lead and evaporated to a certain consistence; but it does not crystallize; it forms a brownish red fluid. Braconnot states, that this acid is contaminated by a mucilaginous matter, between gum and sugar; I find that it is decomposed by long keeping; it deposits a sediment and becomes white.*

4. *The juice of houseleek, (Sempervivum tectorum,) is treated in the same manner, and to remove any excess of sulphuric acid, the fluid is boiled with litharge; sulphuretted hydrogen precipitates the lead; the liquor is evaporated to the consistence of a syrup, alcohol separates the malic acid from some oxalate of lime, distillation removes the alcohol, and water dissolves the remaining acid. Ann. de Chim. et de Phys. Vol. vi. p. 331.*

‡ For which see Ann. de Chim. et de Phys. Vol. vi, and Henry's Chem. Vol. ii, p. 239.

the coloring matter *falls*; the fluid is filtered at a boiling heat; at first the crystals are dark, but after decantation, brilliant white ones appear, and are *decomposed by dilute sulphuric acid*, not sufficient to saturate the lead and the excess is removed by 'sulphuretted hydrogen, (Turner.) Or, saturate the acid juice with chalk, and there is formed a soluble bi-malate of lime, which, by filtration through animal charcoal, becomes colorless and crystallizes; it is decomposed by sulphuric acid.—G-L. Cours, &c.

IV. PROPERTIES.

(a.) *Taste, agreeably acid; inodorous*; formerly described as uncrystallizable, but recently, as crystallizing with difficulty and imperfectly; the solution, when evaporated, becomes thick and syrupy.

(b.) *Very soluble in alcohol and in water*; the watery solution is decomposed by keeping; by nitric acid, it is converted into the oxalic.

(c.) *Heated, away from the air, it sublimes in crystals of a modified acid, called the pyro-malic acid.**

(d.) *Composition*.—Carbon, 40.68 + oxygen, 13.56 + water, 45.76; corresponding to 4 equiv. of carbon = 24 + 1 of oxygen, 8 + 3 of water = 27 = 59 its probable equivalent.† Sheet lead, steeped in apple juice for a few days, forms malate of lead which may be decomposed by dilute sulphuric acid.

MALATES—*Unimportant salts and little known*. In general, they are much more soluble than the oxalates. The malates of potassa and soda are soluble and deliquescent; the malates of lead‡ and lime are very insoluble in cold water, but dissolve easily in boiling water, while the oxalate, tartrate, and citrate of those bases are insoluble even in boiling water.

Remark.—The citric, tartaric and malic are among the principal acids, which, along with sugar, mucilage and other principles, give the flavor to fruits, and we derive from Scheele most of our knowledge on the subject.§

* Ann. de Chim. et de Phys. Vol. xxxiv, p. 271.

† Prout. Phil. Trans. 1827.

‡ The malate of lead, formed between malic acid or a soluble malate and acetate of lead, is at first a white powder, but by keeping for some hours it is converted into beautiful pearly crystals; this is a peculiar property.

§ He states that the expressed juices of *Berberis vulgaris*, the Barberry tree—*Sambucus nigra*, Elder—*Prunus spinosa*, Sloe—*Sorbus aucuparia*, Service—*Prunus domestica*, Garden Plum—afford much malic acid, and little or none of the citric.

Ribes Grossularia, the Hairy Gooseberry, *Ribes rubrum*, the Currant, *Vaccinium Myrtillus*, the Whortleberry, *Cratægus Aria*, Common Lotus, *Prunus Cerasus*, the Cherry, *Fragaria vesca*, the strawberry, *Rubus chamaemorus*, Bilberry, *Rubus idæus*, Raspberry :—appear to contain half of the one and half of the other.

Vaccinium Vitis Idæa, *Vaccinium oxycoccos*, marshwhortle, *Prunus padus*, Bird's Cherry, *Solanum dulcamara*, *Rosa-canina*, Eglantine, Citrus, citron or Lemon :—contain much citric and little or none of the malic acid.

The acid of green grapes and of tamarinds contains citric acid with malic and tartaric.

	Equiv. of base.	Equiv. of acid.	Base.	Acid.	Equiv.
Oxalate contains	1	+	1 = 48	+	36 = 84
Bin-oxalate,	1	+	2 = 48	+	72 = 120
Quadroxalate,	1	+	4 = 48	+	144 = 192 (H.)

IV. OXALATE OF SODA.

(a.) *Formed synthetically.*(b.) *Composition.*—Base 1 equiv. 32 + 1 of acid, 36 = 68 its equivalent; * 100 of soda require 112.5 acid, and as it forms a bin-oxalate, twice as much acid = 225 parts are required in that salt; 1 equiv. base = 32 + 2 of acid = 72 = 104, its equiv.; there is no quadroxalate.

V. OXALATE OF AMMONIA.

(a.) *Formed synthetically.*(b.) *Crytallizes in long transparent prisms; taste bitter.*

(c.) Soluble at 60° in the ratio of 45 grains to 1000 of water; in hot water very soluble, and a saturated solution, on cooling, deposits crystals.

(d.) *Composition.*—Ammonia 1 equiv. 17 + 1 of acid, 36 = 53 the equivalent of the anhydrous salt, and in the crystals there are 2 equiv. of water 18 = 71; there is a bin-oxalate, not so soluble as the oxalate. It is a very useful reagent, especially in detecting lime, and is preferred to oxalic acid, because the latter, by setting free a mineral acid, might cause the resolution of the oxalate of lime, while the acid would be engaged by the ammonia, if the oxalate of that base were used.

VI. OXALATE OF LIME.

(a.) *Formed, between oxalic acid or any soluble oxalate, and lime water, or any soluble calcareous salt; turns syrup of violets green.*(b.) *It is a white powder, insoluble in water, but, when recently precipitated, it is very soluble in nitric and muriatic acids; if, in any water, which we could examine for lime, by means of oxalic acid or a soluble oxalate, nitric or muriatic acid is present in a free state, they must be neutralized before the application of the test; thus, oxalic acid and lime become tests of each other's presence.*(c.) *Decomposed by carbonate of potassa.*(d.) *Composition.*—Lime 1 equiv. 28 + acid 1 equiv. 36 = 64 the equiv. of the salt; per cent. lime 43.75 + acid 56.25 = 100.*If slowly dried, it retains four, if rapidly, six equivalents of water, and it is anhydrous, after being heated to 560° F. which temperature it sustains without decomposition. There is no bin-oxalate. This salt is the basis of the mulberry calculus.*

VII. OXALATE OF BARYTA AND OXALATE OF STRONTIA have nothing interesting, except that the bin-oxalate of baryta is soluble, while the

* The water, contained in the crystals, is not in equivalent proportion and is neglected.

oxalate is nearly insoluble; the latter is converted into the former, by the addition of acid, and its crystals are decomposed, by mere solution in water.

VIII. *OXALATE OF MAGNESIA*, formed by mingling sulphate of magnesia and oxalate of ammonia; if the sulphate has been moderately diluted, with cold water, it is not precipitated until it is heated, although after it has fallen, it is insoluble; as lime is instantly precipitated, this affords the best method known of separating these earths. Among the metallic oxalates, some, as those of nickel and cobalt, afford a pure metal, by ignition.

IX. *The oxalate of lead*, formed by oxalic acid and acetate or nitrate of the metal, *detonates*, by being heated in a tube with bits of potassium.*

X. *The oxalate of mercury*, produced in the same manner, *detonates by heat*, and was formerly supposed to enter into the constitution of Howard's fulminating mercury. Oxalate or bin-oxalate of potassa and antimony, heated together in a covered crucible, afford an alloy of potassium and antimony. Per-oxalate of copper, digested with oxalate of ammonia, affords crystals that detonate by a sudden heat.

II. TARTARIC ACID.

I. NAME AND HISTORY.

Name, from the crude tartar of wine, or from the salt that is purified from it, (cream of tartar,) from which this acid is extracted. *Discovered by Scheele in 1770.*† It exists in several acidulous fruits‡ but always in combination with lime or potassa. *We always extract it from combination*; it is never formed synthetically.

II. *PROCESS*,|| by decomposing the bitartrate of potassa, by chalk. Taking the proportions by the equivalents, they are as follows.§

* H. and Phil. Mag. 1827.

† His first recorded discovery.

‡ Found in the tamarind, in balm, *Carduus benedictus*, roots of resharrow, germander and sage; sumach is quoted in foreign books as containing tartaric acid, but I am reminded by Prof. Tully, that the American *Rhus glabra* affords malic acid, and that this is probably the fact with all the other American acidulous sumachs. —Ann. Lyc. N. York, Vol. 1, p. 42.—I. Cozzens.

|| Or, 100 parts of cream of tartar, 26 1-2 to 30 chalk in 8 or 10 times as much water; add the chalk by portions, when the effervescence ceases, add to the clear liquor a solution of nitrate or muriate of lime, so long as a precipitate falls, wash it and then double as much sulphuric acid as chalk must be added to the tartrate of lime diffused in water, and after 24 hours, the liquor may be examined for sulphuric acid by adding acetate of lead; if the precipitate is only tartrate of lead it will be entirely soluble in diluted nitric acid; if any thing remains, it is sulphate of lead, indicating an excess of sulphuric acid which may be saturated by more chalk, or if the tartrate of lime has not all been decomposed, more sulphuric acid may be added. A little excess of sulphuric acid does no harm, but much would decompose the tartaric acid.

Dr. Henry thinks, that no advantage is gained by substituting quick lime for chalk, for although more of the cream of tartar is decomposed, the liberated potassa dissolves the tartrate of lime and thus prevents its precipitation. With chalk we remove only one equivalent of tartaric acid.—Henry and A. A. Hayes. § Turner.

Powder of cream of tartar (bitartrate of potassa) 198 parts, or one equivalent, intimately mixed with 50, or one equiv. of chalk; throw the mixture, by portions, into 10 parts of boiling water; carbonic acid escapes, with effervescence, and 1 equiv. of tartrate of lime falls, and one of soluble tartrate of potassa remains in solution;* the precipitate is washed, and then diffused through a moderate portion of water, containing one equiv. of sulphuric acid, 49; digestion liberates the tartaric acid, and after the separation of the sulphate of lime by the filter and due evaporation, the acid is obtained in crystals.

III. PROPERTIES.

(a.) *Taste very acid, setting the teeth on edge, but when diluted, it is agreeable; reddens the vegetable blues.*

(b.) *Crystallizes in tables or prisms;† primitive form a right rhombic prism; sp. gr. 1.59.*

(c.) *Soluble in 5 or 6 parts of water at 60°, and in much less of boiling water, a saturated solution, sp. gr. 1.230, becomes mouldy on the surface by keeping; soluble in alcohol.*

(d.) *By strong nitric acid, converted into oxalic.*

(e.) *Does not precipitate lime from the mineral acids, but separates it from the vegetable; it precipitates baryta and strontia.*

(f.) *Composition.*—By the researches of the most distinguished analysts, it appears, that *this acid contains about two thirds of its weight of oxygen; from one quarter to one third of carbon, and a small portion of hydrogen.* Dr. Henry gives, as the most probable constitution,

Carbon	4 equiv.	24	36.36
Oxygen	5 “	40	60.61
Hydrogen	2 “	—	23.03

66 100.—And the crystals consist of anhydrous acid 1 equiv. 66+1 water 9=75; per cent. 88.16 acid + 11.84 water.‡

(g.) *Destructive distillation gives pyro-tartaric acid§ besides the usual products* of much inflammable and other gases, and charcoal remains. *The acid rises in sublimation* and is also dissolved in the fluid; *it affords crystals*, which, by heat, give a white sublimate; its distinct character has been both admitted and denied, and is now admitted again.

* It may be decomposed by muriate of lime and the insoluble tartrate of lime, by sulphuric acid, as before, or it may be reserved as tartrate of potassa for other purposes.

† The appearance of the crystals is often confused; in plates, needles, leaves, pyramids, prisms, groups, &c.

‡ Prout, Phil. Trans. 1827.—Thomson's First Principles, II, 115.

§ This has been supposed to be the acetic, disguised by oil; it differs from the tartaric in the compounds it forms; it does not precipitate baryta or lime, or form a salt of sparing solubility with potassa.

IV. USES.—*The tartaric acid is so intensely sour, as to require large dilution with water, when taken as a beverage.*

It is given in the military hospitals as a cooling drink, and its use in soda powders has been already stated. It is free from the rough taste of cream of tartar, and is one of the most agreeable and permanent of the vegetable acids; its crystals undergo no change by weather, climate or time.*

It is now largely manufactured and sold in the shops, under the name of tartaric acid, and is an agreeable substitute for lemonade.

TARTRATES.

1. The tartrates consist of tartaric acid, and a base, which, when they are decomposed by heat, is generally left, mixed with charcoal.

2. The bi-tartrates are less soluble than the tartrates, in this respect resembling the oxalates; the earthy tartrates are generally insoluble, and are obtained by double decomposition.

3. All the soluble tartrates form bi-tartrates of sparing solubility, while the insoluble tartrates may be dissolved, in an excess of their own acid.

4. The tartaric acid is prone to unite with two bases, at once, to form double salts.

I. BI-TARTRATE OF POTASSA.—Cream of tartar.

I. ORIGIN.—*Exists in many vegetables and fruits,† and is produced by the fermentation of the juice of grapes, especially those affording the red and Rhenish wines; the salt, as it forms during the fermentation, is deposited on the interior of the wine casks,‡ and from this substance, called tartar, or crude, or wine tartar, or argal, the cream of tartar, bi-tartrate of potassa, is prepared.§*

The process consists, as in the case of bin-oxalate of potassa, in solutions, filtrations and crystallizations, clay or whites of eggs being used, to clarify the fluid. *The crust of crystals, that appears on the surface, being skimmed like cream, and hence the origin of the appellation, cream of tartar.*

II. PROPERTIES.

(a.) *Crystals, irregular six sided prisms|| with six terminating faces; the primary form, a right prism rectangular or rhombic. Sp. gr. 1.953.*

(b.) *Taste, acid and rough; brittle; reddens the vegetable blues.*

* Vol. I, p. 383.

† It is abundant in the tamarind.

‡ It is knocked off and sold under the name of wine stone; it often contains or copies the fibres of the cask, and is colored more or less deeply by the wine.

§ Rozier, Jour. de Ph. Vol. I, p. 67.—Memoires de la Academie, 1725, and Fourcroy, Vol. VII, p. 319.

|| For a more exact account of their form, see Thomson's Annals, Vol. X, p. 37, and N. S. Vol. VII, p. 161.

The other earthy tartrates are formed, in general, by double exchange, between the tartrate of potassa and a soluble salt of the earth.

7. METALLIC TARTRATES.—That of antimony and potassa is the only important one, (see antimony p. 212.)

The tartrate of lead, formed between acetate of lead and tartaric acid or tartrate of potassa, is a white powder, and when warmed in a tube and poured out into the air it is a *pyrophorus*.

Tartrate of mercury is an insoluble white powder; a triple compound is formed between 6 parts of cream of tartar and 1 oxide of mercury by boiling.

III. CITRIC ACID.

I. NAME, from *Citrus*, the lemon or orange, which contains it in abundance; *discovered by Mr. Scheele*, of Sweden.

II. PROCESS.*

(a.) *Lime or lemon juice is neutralized by chalk, and the citrate of lime is decomposed by sulphuric acid.*

(b.) Saturate the expressed juice by powdered chalk,† with agitation; after subsidence of the solid citrate of lime decant the water, add more, repeatedly, till there is no taste or color in the fluid.

(c.) To the solid citrate,‡ constantly stirred, add as much sulphuric acid, of a density not far from 1.85, diluted with 10 parts of water; stir the mixture, occasionally, for 24 hours; let the sulphate of lime subside; add water, till it comes off tasteless; mix the liquors,§ and evaporate to $\frac{1}{4}$, and more sulphate of lime will fall; evaporate again to the density of a syrup, and brown crystals will form, which are purified by repeated solutions and crystallizations.

III. PROPERTIES.

(a.) *Crystallizes in large rhomboidal tables or prisms; transparent and beautiful; primitive form, a right rhombic prism.*

* As citric acid has become an important article of commerce, much attention is now paid to the details of the manufacture, a full account of which may be found in *Parkes' Chemical Essays*, and in the 46th Vol. of the *Phil. Mag.* See also *Henry's Chem.* 11th edition, Vol. II, p. 228.

† According to Dr. Henry's experience, 6 or 8 oz. of chalk will saturate a wine gallon of lemon juice, and in 1 gallon, he has found even 12 oz. of solid citric acid, but it averages about 6 or 8 oz. to 1 gallon; for a method of estimating the proportion with sufficient accuracy, see *Henry's Chem.* Vol. II, p. 229, 11th edition.

‡ The equivalents are dry citrate of lime, 86, + 49 of strong sulphuric acid diluted with 10 of water. In general, 90 parts of lemon juice (94 Proust,) require 4 parts of chalk for saturation, which produce 6 parts, (7 1-2 Proust,) of citrate of lime, and 18 parts (20 Proust,) of sulphuric acid are necessary for their decomposition.

§ They may contain a little sulphuric acid and mucilage; the former is detected by acetate of lead, and may be neutralized by more citrate of lime; but a little does no harm, as the citric acid crystallizes and leaves the sulphuric, and also the mucilage. If there is lime in excess, the citric acid will not crystallize.

(b.) *Crystals*, often irregular six sided *prisms*, with dihedral summits; primitive form, a right rhomboidal prism.

(c.) *Composition*.—Acid 1 equiv. $66 + 1$ potassa $48 = 114$, and in the crystals, 2 equiv. of water $18 = 132$; a heat of 248° F. expels the water without decomposing the acid; per cent. the anhydrous salt contains acid $57.90 +$ potassa 42.10 .

IV. *USES*.—*Chiefly medical*; it is the soluble tartar of the physician, and is frequently formed in the first mode named above.

Remark.—Such is the tendency of tartaric acid to form an insoluble bi-tartrate, with potassa, that it takes that alkali even from the mineral acids—e. g. from the muriate of potassa, and when tartaric acid is added to a solution of tartrate of potassa, a white powder falls, which is the bi-tartrate. If to a strong solution of tartaric acid, we add half enough of potassa to saturate the acid, there will be a precipitate of bi-tartrate; if as much more alkali is added, it will be redissolved and the precipitate will be renewed on adding an acid, e. g. the muriatic.

3. TARTRATE OF POTASSA AND SODA.—*Salt of Seignette,* Rochelle salt.**

I. PROCESS.

(a.) *By saturating cream of tartar*, 18 parts, with sub-carbonate of soda, 18.

II. PROPERTIES.

(a.) *The crystals are often large and very beautiful*; form prismatic, or rhomboidal prisms, with 10 or 12 sides.

(b.) *Soluble in 5 parts of cold*, and in much less of boiling water; taste, bitter.

(c.) *Composition*.—Tartrate of potassa $54 +$ tartrate of soda 46 , which are almost exactly the equivalent proportions.

III. USES.—*A valuable medicine.*

The cream of tartar is so prone to combine with an additional base, that it often acts as a simple acid, and dissolves oxides that are insoluble in the mineral acids, and even in the tartaric.†

4. TARTRATE OF SODA.—It has been already mentioned, as being formed, when the soda powders are mixed; carbonate of soda is better adapted than carbonate of potassa to that use, because it is less prone to form an insoluble bi-salt. The crystals of tartrate of soda are fine needles.

5. TARTRATE OF AMMONIA is formed synthetically; bitter, very soluble; forms an insoluble bi-tartrate.

6. EARTHY TARTRATES.—The tartrate of lime is produced, as already mentioned, in the process for tartaric acid; it has no other use.

* From the apothecary by whom, and the place at which, this salt was first formed.
† Ann. de Ch. et de Ph. Vol. III, p. 281, and H.

The other earthy tartrates are formed, in general, by double exchange, between the tartrate of potassa and a soluble salt of the earth.

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III. CITRIC ACID.

I. NAME, from *Citrus*, the lemon or orange, which contains it in abundance; discovered by Mr. Scheele, of Sweden.

II. PROCESS.*

(a.) *Lime or lemon juice is neutralized by chalk, and the citrate of lime is decomposed by sulphuric acid.*

(b.) Saturate the expressed juice by powdered chalk,† with agitation; after subsidence of the solid citrate of lime decant the water, add more, repeatedly, till there is no taste or color in the fluid.

(c.) To the solid citrate,‡ constantly stirred, add as much sulphuric acid, of a density not far from 1.85, diluted with 10 parts of water; stir the mixture, occasionally, for 24 hours; let the sulphate of lime subside; add water, till it comes off tasteless; mix the liquors,§ and evaporate to $\frac{1}{2}$, and more sulphate of lime will fall; evaporate again to the density of a syrup, and brown crystals will form, which are purified by repeated solutions and crystallizations.

III. PROPERTIES.

(a.) *Crystallizes in large rhomboidal tables or prisms; transparent and beautiful; primitive form, a right rhombic prism.*

* As citric acid has become an important article of commerce, much attention is now paid to the details of the manufacture, a full account of which may be found in Parkes' Chemical Essays, and in the 46th Vol. of the Phil. Mag. See also Henry's Chem. 11th edition, Vol. 11, p. 223.

† According to Dr. Henry's experience, 6 or 8 oz. of chalk will saturate a wine gallon of lemon juice, and in 1 gallon, he has found even 12 oz. of solid citric acid, but it averages about 6 or 8 oz. to 1 gallon; for a method of estimating the proportion with sufficient accuracy, see Henry's Chem. Vol. 11, p. 229, 11th edition.

‡ The equivalents are dry citrate of lime, 86, + 49 of strong sulphuric acid diluted with 10 of water. In general, 90 parts of lemon juice (94 Proust,) require 4 parts of chalk for saturation, which produce 6 parts, (7 1-2 Proust,) of citrate of lime, and 18 parts (20 Proust,) of sulphuric acid are necessary for their decomposition.

§ They may contain a little sulphuric acid and mucilage; the former is detected by acetate of lead, and may be neutralized by more citrate of lime; but a little does no harm, as the citric acid crystallizes and leaves the sulphuric, and also the mucilage. If there is lime in excess, the citric acid will not crystallize.

(b.) *Crystals, permanent* in the air*; lose about 7 pr. ct. by being heated, to the point just below decomposition; *endure all climates and vicissitudes of weather, unchanged*, but the aqueous solution, like those of most vegetable bodies, is slowly decomposed by keeping.

(c.) *Taste very acid*, but agreeable, and *not corrosive*; in solution with water, it is *grateful*; *reddens the vegetable blues*; soluble in $1\frac{1}{2}$ part of cold water, and in half its weight of boiling water.

(d.) *Nitric acid*, 3 parts, *converts it into the oxalic*, half a part, and by increasing the proportion of the nitric, it is essentially converted into the acetic acid.

(e.) *Composition*.—The most eminent chemists have obtained different proportions; but the most probable constitution, deduced from the experiments of Thomson and Berzelius, appears to be, carbon 4 equiv. = 24, and oxygen 4 = 32, hydrogen 2 = 58, the equiv. of the acid.†

(f.) *Destructive distillation affords the usual products of vegetable decomposition, and also an acid*, supposed to be a peculiar one; it is called the *pyro-citric*, but if a distinct acid, it is not important.‡

IV. *USES*.—*Tartaric acid is carried to sea as an antidote to scurvy*; it affords an excellent substitute for lemonade; it is necessary only to dissolve it in about 19 parts of water with sufficient sugar, and add the essential oil of lemons. It may be mixed, in the proportion of half an ounce with one pound of sugar, and this may be essenced by 5 or 6 drops of oil of lemons on a lump of sugar.

It was, many years ago, suggested by Fourcroy, that the juice of limes and lemons might, in the West Indies, be saturated with lime or chalk, and then exported to Europe for decomposition by sulphuric acid; this is now done with advantage.

Citric acid is often employed in making the effervescing mixture, with carbonate of potassa or soda. It removes iron stains in the same manner as oxalic acid. It is used by dyers, to enliven the color of the safflower, and to produce a fine red with tin and cochineal, especially for silk and morocco. Like tartaric acid, it whitens and hardens tallow. As the tartaric acid is cheaper than the citric, it is sometimes used to adulterate it, and may be discovered, by adding carbonate of potassa, which, if tartaric acid be present, will precipitate cream of tartar.

* I have one nearly an inch square, formed in London, (July 1803,) which remains unchanged after twenty five years; the acid in the entire solution, placed in Mr. Accum's garret and forgotten, was found to have been absorbed into a single crystal, doubtless at the expense of many smaller ones, in the manner pointed out by Dr. Wollaston, (Faraday's Chem. Manip. p. 253.) In general, great quantities of fluids are necessary to produce large and fine crystals, according to the method of Mr. Dizé in Paris.

† For different views, see Henry, 11th edition, Vol. II, p. 231, and Phil. Trans. 1812; also Gray's Operative Chemist.

‡ See Henry, Vol. II, p. 233.

Oxalic acid is found, free, in the juice of the fibres or hair of chick pease;* it exudes, when they are cut by scissors, and persons who walk over a field of chick pease, have their shoes burned by this acid.

IV. *Miscellaneous*.—When† carbonic acid and carbonic oxide are produced, by heating oxalic acid or the bin-oxalate of potassa, with sulphuric acid, the carbonic acid is removed by lime water or potassa, and the carbonic oxide remains; the sulphuric acid is not decomposed and appears to operate by removing water, and the elements of the oxalic acid arrange themselves anew.

Oxalic acid and the oxalates, boiled with a solution of gold, reduce the oxide, and produce carbonic acid.

The greater part of the oxalic acid used in the arts, in the manufacture of printed goods, is obtained by the action of nitric acid upon sugar or starch; with starch 1 part, and nitric acid 6, added at intervals and aided by heat, they obtain more than half the weight of the starch in oxalic acid.‡ Oxalic acid takes lime from every acid, even the sulphuric and the phosphoric.§

OXALATES.

1. Composed of oxalic acid and bases; most of them unimportant.
2. *Generally insoluble, or sparingly soluble* in water; soluble in nitric and in muriatic acid.||

3. The oxalates of potassa, soda, lithia, alumina and iron are the most soluble.¶

4. From a soluble oxalate, a neutral salt of lime or of lead throws down an insoluble oxalate, which is decomposed by sulphuric acid, forming an insoluble sulphate, and crystals of oxalic acid are obtained on cooling.

5. All insoluble oxalates, the bases of which form insoluble compounds with sulphuric acid, may be decomposed in a similar manner, and all other insoluble oxalates, by potassa, and soluble oxalates formed.

6. *Decomposed at ignition*; no charcoal is left, being burned by the oxygen of the acid, and a carbonate remains, if the base can retain carbonic acid, or if the heat be pushed, the base alone remains, (ammonia excepted.)

7. *Some oxalates are metallized by ignition*, emitting pure carbonic acid; the 1 equivalent in the neutral protoxide being transferred to the oxalic acid, to form carbonic acid.**

8. *Decomposed by hot sulphuric acid*, generating carbonic acid and carbonic oxide.

* Fourcroy, Vol. VII, p. 302. Chaptal, Vol. III, p. 115.

† Ann de Ch. et de Ph. Vol. XIX, p. 84; see also this work, Vol. I, p. 396, (g.)

‡ Langier's Cours, &c. Vol. III, p. 211. § Except, perhaps, the fluoric.

¶ Except where the latter precipitates the bases of the salts.

‡ An additional equivalent of acid does not render the alkaline oxalates more, but less soluble, contrary to the general state of facts among saline bodies.

** Gay-Lussac, Turner.

I. BIN-OXALATE OF POTASSA, or salt of sorrel of the shops.

I. ORIGIN.—Already stated to be found native in the sorrels, and in many other vegetables; that of commerce comes chiefly from Switzerland; it is very white, and is extracted from the *Rumex acetosella*, gathered in June; that of Thuringia is yellowish and is from the *Oxalis acetosella*. The plants are repeatedly bruised, macerated and pressed, and from the fluid, crystals are obtained by evaporation. It is easily formed synthetically.

II. PROPERTIES.

(a.) *Taste acrid and bitter*; soluble at 60° in 10 parts of water, and in less at 212° ; crystals rhomboidal parallelopipeds, resembling cubes; reddens vegetable blues.

(b.) *Composition*.—Acid 2 equiv. $72 +$ alkali one, $48 +$ water two $18 = 138$ its equivalent.

(c.) *It is used to remove iron and ink stains*, which it does by transferring 1 equivalent of the acid to the iron, thus forming a soluble oxalate of iron and leaving a soluble oxalate of potassa.*

II. OXALATE OF POTASSA.

I. *Preparation, by saturating oxalic acid or the bin-oxalate with potassa or its carbonate.*

II. PROPERTIES.

(a.) *The crystals are oblique prisms of four sides; taste bitter and cool*; soluble at 60° , in 2 parts of water.

(b.) *Composition*, acid 1 equiv. $36 +$ 1 equiv. of potassa, $48 +$ 1 of water, $9 = 93$ its equiv. *Much used as a test for lime*, with which it forms an insoluble precipitate, provided there is no free mineral acid in the water, which would redissolve the precipitate. It is remarkable, that the oxalate is much more soluble than the bin-oxalate, contrary to the general analogy of salts.

III. QUADROXALATE OF POTASSA.

I. *PREPARATION*.—*By digesting the bin-oxalate with nitric or muriatic acid*, which takes half the base and leaves the other half, combined with the whole of the acid, and of course with four equivalents.

II. PROPERTIES.

(a.) *Forms beautiful crystals*, which are obtained pure by a second crystallization.

(b.) The alkali, remaining from the decomposition of 3 parts of this salt, by heat, exactly saturates the acid in one part of the crystals.

(c.) Hence, it contains 4 equivalents of acid $= 144 +$ one of alkali $48 +$ 7 of water, $= 63 = 255$ its equivalent. We owe this beautiful proof of the truth of the law of multiple proportions to Dr. Wollaston.†

* Aromatized, by oil of lemons, it is used as an acidulous drink in some diseases; it is antiseptic, and will preserve meat.

† Phil. Trans, 1808, p. 99. See also Beqard, Ann. de Chim. Vol. LXXIII, p. 371.

	Equiv. of base.	Equiv. of acid.	Base.	Acid.	Equiv.
Oxalate contains	1	+	1 = 48	+	36 = 84
Bin-oxalate,	1	+	2 = 48	+	72 = 120
Quadroxalate,	1	+	4 = 48	+	144 = 192 (H.)

IV. OXALATE OF SODA.

(a.) *Formed synthetically.*

(b.) *Composition.*—Base 1 equiv. 32 + 1 of acid, 36 = 68 its equivalent; * 100 of soda require 112.5 acid, and as it forms a bin-oxalate, twice as much acid = 225 parts are required in that salt; 1 equiv. base = 32 + 2 of acid = 72 = 104, its equiv.; there is no quadroxalate.

V. OXALATE OF AMMONIA.

(a.) *Formed synthetically.*

(b.) *Crystallizes in long transparent prisms; taste bitter.*

(c.) Soluble at 60° in the ratio of 45 grains to 1000 of water; in hot water very soluble, and a saturated solution, on cooling, deposits crystals.

(d.) *Composition.*—Ammonia 1 equiv. 17 + 1 of acid, 36 = 53 the equivalent of the anhydrous salt, and in the crystals there are 2 equiv. of water 18 = 71; there is a bin-oxalate, not so soluble as the oxalate. *It is a very useful reagent, especially in detecting lime,* and is preferred to oxalic acid, because the latter, by setting free a mineral acid, might cause the resolution of the oxalate of lime, while the acid would be engaged by the ammonia, if the oxalate of that base were used.

VI. OXALATE OF LIME.

(a.) *Formed, between oxalic acid or any soluble oxalate, and lime water, or any soluble calcareous salt; turns syrup of violets green.*

(b.) *It is a white powder, insoluble in water, but, when recently precipitated, it is very soluble in nitric and muriatic acids; if, in any water, which we could examine for lime, by means of oxalic acid or a soluble oxalate, nitric or muriatic acid is present in a free state, they must be neutralized before the application of the test; thus, oxalic acid and lime become tests of each other's presence.*

(c.) *Decomposed by carbonate of potassa.*

(d.) *Composition.*—Lime 1 equiv. 28 + acid 1 equiv. 36 = 64 the equiv. of the salt; per cent. lime 43.75 + acid 56.25 = 100.

If slowly dried, it retains four, if rapidly, six equivalents of water, and it is anhydrous, after being heated to 560° F. which temperature it sustains without decomposition. There is no bin-oxalate. This salt is the basis of the mulberry calculus.

VII. OXALATE OF BARYTA AND OXALATE OF STRONTIA have nothing interesting, except that the bin-oxalate of baryta is soluble, while the

* The water, contained in the crystals, is not in equivalent proportion and is neglected.

oxalate is nearly insoluble; the latter is converted into the former, by the addition of acid, and its crystals are decomposed, by mere solution in water.

VIII. *OXALATE OF MAGNESIA, formed by mingling sulphate of magnesia and oxalate of ammonia*; if the sulphate has been moderately diluted, with cold water, it is not precipitated until it is heated, although after it has fallen, it is insoluble; as lime is instantly precipitated, this affords the best method known of separating these earths. Among the metallic oxalates, some, as those of nickel and cobalt, afford a pure metal, by ignition.

IX. *The oxalate of lead, formed by oxalic acid and acetate or nitrate of the metal, detonates, by being heated in a tube with bits of potassium.**

X. *The oxalate of mercury, produced in the same manner, detonates by heat, and was formerly supposed to enter into the constitution of Howard's fulminating mercury.* Oxalate or bin-oxalate of potassa and antimony, heated together in a covered crucible, afford an alloy of potassium and antimony. Per-oxalate of copper, digested with oxalate of ammonia, affords crystals that detonate by a sudden heat.

II. TARTARIC ACID.

I. NAME AND HISTORY.

Name, from the crude tartar of wine, or from the salt that is purified from it, (cream of tartar,) from which this acid is extracted. Discovered by Scheele in 1770.† It exists in several acidulous fruits‡ but always in combination with lime or potassa. *We always extract it from combination*; it is never formed synthetically.

II. *PROCESS,|| by decomposing the bitartrate of potassa, by chalk.* Taking the proportions by the equivalents, they are as follows.§

* H. and Phil. Mag. 1827.

† His first recorded discovery.

‡ Found in the tamarind, in balm, *Carduus benedictus*, roots of reisharrow, germander and sage; sumach is quoted in foreign books as containing tartaric acid, but I am reminded by Prof. Tully, that the American *Rhus glabra* affords mallic acid, and that this is probably the fact with all the other American acidulous sumachs. —Ann. Lyc. N. York, Vol. i, p. 42.—I. Cozzens.

|| Or, 100 parts of cream of tartar, 26 1-2 to 30 chalk in 8 or 10 times as much water; add the chalk by portions, when the effervescence ceases, add to the clear liquor a solution of nitrate or muriate of lime, so long as a precipitate falls, wash it and then double as much sulphuric acid as chalk must be added to the tartrate of lime diffused in water, and after 24 hours, the liquor may be examined for sulphuric acid by adding acetate of lead; if the precipitate is only tartrate of lead it will be entirely soluble in diluted nitric acid; if any thing remains, it is sulphate of lead, indicating an excess of sulphuric acid which may be saturated by more chalk, or if the tartrate of lime has not all been decomposed, more sulphuric acid may be added. A little excess of sulphuric acid does no harm, but much would decompose the tartaric acid.

Dr. Henry thinks, that no advantage is gained by substituting quick lime for chalk, for although more of the cream of tartar is decomposed, the liberated potassa dissolves the tartrate of lime and thus prevents its precipitation. With chalk we remove only one equivalent of tartaric acid.—Henry and A. A. Hayes. § Turner.

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III. PROPERTIES.

(a.) *Taste very acid*, setting the teeth on edge, but when diluted, it is agreeable; *reddens the vegetable blues*.

(b.) *Crystallizes in tables or prisms*;† primitive form a right rhombic prism; sp. gr. 1.59.

(c.) *Soluble in 5 or 6 parts of water at 60°*, and in much less of boiling water, a saturated solution, sp. gr. 1.230, becomes mouldy on the surface by keeping; soluble in alcohol.

(d.) By strong nitric acid, converted into oxalic.

(e.) *Does not precipitate lime from the mineral acids*, but separates it from the vegetable; it precipitates baryta and strontia.

(f.) *Composition*.—By the researches of the most distinguished analysts, it appears, that *this acid contains about two thirds of its weight of oxygen; from one quarter to one third of carbon, and a small portion of hydrogen*. Dr. Henry gives, as the most probable constitution,

Carbon	4 equiv.	24	36.36
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66 100.—And the crystals

consist of anhydrous acid 1 equiv. 66+1 water 9=75; per cent. 88.16 acid + 11.84 water.‡

(g.) *Destructive distillation gives pyro-tartaric acid§ besides the usual products* of much inflammable and other gases, and charcoal remains. *The acid rises in sublimation* and is also dissolved in the fluid; it *affords crystals*, which, by heat, give a white sublimate; its distinct character has been both admitted and denied, and is now admitted again.

* It may be decomposed by muriate of lime and the insoluble tartrate of lime, by sulphuric acid, as before, or it may be reserved as tartrate of potassa for other purposes.

† The appearance of the crystals is often confused; in plates, needles, leaves, pyramids, prisms, groups, &c.

‡ Prout, Phil. Trans. 1827.—Thomson's First Principles, II, 115.

§ This has been supposed to be the acetic, disguised by oil; it differs from the tartaric in the compounds it forms; it does not precipitate baryta or lime, or form a salt of sparing solubility with potassa.

IV. USES.—*The tartaric acid is so intensely sour, as to require large dilution with water, when taken as a beverage.*

It is given in the military hospitals as a cooling drink, and its use in soda powders has been already stated. It is free from the rough taste of cream of tartar, and is one of the most agreeable and permanent of the vegetable acids; its crystals undergo no change by weather, climate or time.*

It is now largely manufactured and sold in the shops, under the name of tartaric acid, and is an agreeable substitute for lemonade.

TARTRATES.

1. The tartrates consist of tartaric acid, and a base, which, when they are decomposed by heat, is generally left, mixed with charcoal.

2. The bi-tartrates are less soluble than the tartrates, in this respect resembling the oxalates; the earthy tartrates are generally insoluble, and are obtained by double decomposition.

3. All the soluble tartrates form bi-tartrates of sparing solubility, while the insoluble tartrates may be dissolved, in an excess of their own acid.

4. The tartaric acid is prone to unite with two bases, at once, to form double salts.

I. BI-TARTRATE OF POTASSA.—Cream of tartar.

I. ORIGIN.—*Exists in many vegetables and fruits,† and is produced by the fermentation of the juice of grapes, especially those affording the red and Rhenish wines; the salt, as it forms during the fermentation, is deposited on the interior of the wine casks,‡ and from this substance, called tartar, or crude, or wine tartar, or argal, the cream of tartar, bi-tartrate of potassa, is prepared.§*

The process consists, as in the case of bin-oxalate of potassa, in solutions, filtrations and crystallizations, clay or whites of eggs being used, to clarify the fluid. *The crust of crystals, that appears on the surface, being skimmed like cream, and hence the origin of the appellation, cream of tartar.*

II. PROPERTIES.

(a.) *Crystals, irregular six sided prisms|| with six terminating faces; the primary form, a right prism rectangular or rhombic. Sp. gr. 1.953.*

(b.) *Taste, acid and rough; brittle; reddens the vegetable blues.*

* Vol. i, p. 883.

† It is abundant in the tamarind.

‡ It is knocked off and sold under the name of wine stone; it often contains or copies the fibres of the cask, and is colored more or less deeply by the wine.

§ Rozier, Jour. de Ph. Vol. i, p. 67.—Memoires de la Academie, 1725, and Fourcroy, Vol. vii, p. 319.

|| For a more exact account of their form, see Thomson's Annals, Vol. x, p. 37, and N. S. Vol. vii, p. 161.

(c.) *Soluble in 60 parts of water at 60° F., and in 14 at 212°; hence, it crystallizes very rapidly by cooling, but falls rather in grains than distinct crystals.*

(d.) *Composition.*—It appears to consist of

Acid, 2 equiv.	132	73.89 per cent.
Potassa, 1 “	48	26.11
	180	100.

To the number 180, we must add the water in its crystals, 1² equiv. or 2†; it cannot be separated without decomposing the acid.

That it contains 2 equiv. of acid is proved by the fact, that the alkali which remains from the incineration of a given weight, precisely saturates the same weight of the crystals, dissolved in water.

(e.) *Destructive distillation, besides a great volume of gases and empyreumatic acid and oil, affords in the residuum, carbonate of potassa† about one third of the weight, formerly called, on account of its origin, salt of tartar; it is generally regarded as pure,§ but a little lime and silica, and a trace of alumina, iron and manganese have been observed.||*

III. *Uses.*—*A mild and valuable medicine;¶ with oxide of antimony forms tartar emetic,** affords tartaric acid and soluble tartar,†† and black and white flux;‡‡ it appears to be concerned in giving the peculiar roughness to the red wines. It is used in dyeing, felting, gilding, domestic processes, &c.*

II. TARTRATE OF POTASSA.—*Soluble tartar.*

I. *ORIGIN.*—*Found in the juice of ripe grapes, and other pulpy fruits; most abundant in the red grape.*

II. *PROCESS.*

(a.) *By saturating the solution of the super or bi-tartrate, by carbonate of potassa; it is always thus formed, in the first step for obtaining tartaric acid.*

(b.) *By saturating tartaric acid§§ in the same manner till, in both cases, effervescence ceases.*

III. *PROPERTIES.*

(a.) *Very soluble and even deliquescent; decomposed by most acids, bi-tartrate of potassa being deposited; during the fermentation of wines, it is decomposed by the carbonic acid, which takes one half its base, and most of the bi-salt then falls.*

* Thomson.

† Berzelius.

‡ Mixed with charcoal, which is removed by solution and filtration.

§ Especially free from soda, and was therefore used, by Gay-Lussac and Thénard in preparing pure potassium.

|| Ann. de Ch. Vol. LXIV, p. 48.

¶ Dose half an oz. to 1 oz. and less as an aperient or alterative.

** See p. 212 of this Volume.

†† See those articles.

‡‡ Vol. I, p. 470.

§§ 112 of acid to 120 of sub-carbonate and 100 of cream of tartar to 481.2 of sub-carbonate.—H.

(b.) *Crystals*, often irregular six sided *prisms*, with dihedral summits; primitive form, a right rhomboidal prism.

(c.) *Composition*.—Acid 1 equiv. $66 + 1$ potassa $48 = 114$, and in the crystals, 2 equiv. of water $18 = 132$; a heat of 248° F. expels the water without decomposing the acid; per cent. the anhydrous salt contains acid 57.90 + potassa 42.10.

IV. *USES*.—*Chiefly medical*; it is the soluble tartar of the physician, and is frequently formed in the first mode named above.

Remark.—Such is the tendency of tartaric acid to form an insoluble bi-tartrate, with potassa, that it takes that alkali even from the mineral acids—e. g. from the muriate of potassa, and when tartaric acid is added to a solution of tartrate of potassa, a white powder falls, which is the bi-tartrate. If to a strong solution of tartaric acid, we add half enough of potassa to saturate the acid, there will be a precipitate of bi-tartrate; if as much more alkali is added, it will be redissolved and the precipitate will be renewed on adding an acid, e. g. the muriatic.

3. TARTRATE OF POTASSA AND SODA.—*Salt of Seignette,* Rochelle salt.**

I. PROCESS.

(a.) *By saturating cream of tartar*, 18 parts, with *sub-carbonate of soda*, 18.

II. PROPERTIES.

(a.) *The crystals are often large and very beautiful*; form prismatic, or rhomboidal prisms, with 10 or 12 sides.

(b.) *Soluble in 5 parts of cold*, and in much less of boiling water; taste, bitter.

(c.) *Composition*.—Tartrate of potassa $54 +$ tartrate of soda 46, which are almost exactly the equivalent proportions.

III. USES.—*A valuable medicine.*

The cream of tartar is so prone to combine with an additional base, that it often acts as a simple acid, and dissolves oxides that are insoluble in the mineral acids, and even in the tartaric.†

4. TARTRATE OF SODA.—It has been already mentioned, as being formed, when the soda powders are mixed; carbonate of soda is better adapted than carbonate of potassa to that use, because it is less prone to form an insoluble bi-salt. The crystals of tartrate of soda are fine needles.

5. TARTRATE OF AMMONIA is formed synthetically; bitter, very soluble; forms an insoluble bi-tartrate.

6. EARTHY TARTRATES.—The tartrate of lime is produced, as already mentioned, in the process for tartaric acid; it has no other use.

* From the apothecary by whom, and the place at which, this salt was first formed.

† Ann. de Ch. et de Ph. Vol. III, p. 281, and H.

The other earthy tartrates are formed, in general, by double exchange, between the tartrate of potassa and a soluble salt of the earth.

7. METALLIC TARTRATES.—That of antimony and potassa is the only important one, (see antimony p. 212.)

The tartrate of lead, formed between acetate of lead and tartaric acid or tartrate of potassa, is a white powder, and when warmed in a tube and poured out into the air it is a *pyrophorus*.

Tartrate of mercury is an insoluble white powder; a triple compound is formed between 6 parts of cream of tartar and 1 oxide of mercury by boiling.

III. CITRIC ACID.

I. NAME, from *Citrus*, the lemon or orange, which contains it in abundance; discovered by Mr. Scheele, of Sweden.

II. PROCESS.*

(a.) *Lime or lemon juice is neutralized by chalk, and the citrate of lime is decomposed by sulphuric acid.*

(b.) Saturate the expressed juice by powdered chalk,† with agitation; after subsidence of the solid citrate of lime decant the water, add more, repeatedly, till there is no taste or color in the fluid.

(c.) To the solid citrate,‡ constantly stirred, add as much sulphuric acid, of a density not far from 1.85, diluted with 10 parts of water; stir the mixture, occasionally, for 24 hours; let the sulphate of lime subside; add water, till it comes off tasteless; mix the liquors,§ and evaporate to $\frac{1}{2}$, and more sulphate of lime will fall; evaporate again to the density of a syrup, and brown crystals will form, which are purified by repeated solutions and crystallizations.

III. PROPERTIES.

(a.) *Crystallizes in large rhomboidal tables* or prisms; transparent and beautiful; primitive form, a right rhombic prism.

* As citric acid has become an important article of commerce, much attention is now paid to the details of the manufacture, a full account of which may be found in Parkes' Chemical Essays, and in the 46th Vol. of the Phil. Mag. See also Henry's Chem. 11th edition, Vol. 11, p. 228.

† According to Dr. Henry's experience, 6 or 8 oz. of chalk will saturate a wine gallon of lemon juice, and in 1 gallon, he has found even 12 oz. of solid citric acid, but it averages about 6 or 8 oz. to 1 gallon; for a method of estimating the proportion with sufficient accuracy, see Henry's Chem. Vol. 11, p. 229, 11th edition.

‡ The equivalents are dry citrate of lime, 86, + 49 of strong sulphuric acid diluted with 10 of water. In general, 90 parts of lemon juice (94 Proust,) require 4 parts of chalk for saturation, which produce 6 parts, (7 1-2 Proust,) of citrate of lime, and 18 parts (20 Proust,) of sulphuric acid are necessary for their decomposition.

§ They may contain a little sulphuric acid and mucilage; the former is detected by acetate of lead, and may be neutralized by more citrate of lime; but a little does no harm, as the citric acid crystallizes and leaves the sulphuric, and also the mucilage. If there is lime in excess, the citric acid will not crystallize.

(b.) *Crystals, permanent* in the air*; lose about 7 pr. ct. by being heated, to the point just below decomposition; *endure all climates and vicissitudes of weather, unchanged*, but the aqueous solution, like those of most vegetable bodies, is slowly decomposed by keeping.

(c.) *Taste very acid*, but agreeable, and *not corrosive*; in solution with water, it is *grateful*; *reddens the vegetable blues*; soluble in $1\frac{1}{2}$ part of cold water, and in half its weight of boiling water.

(d.) *Nitric acid*, 3 parts, *converts it into the oxalic*, half a part, and by increasing the proportion of the nitric, it is essentially converted into the acetic acid.

(e.) *Composition*.—The most eminent chemists have obtained different proportions; but the most probable constitution, deduced from the experiments of Thomson and Berzelius, appears to be, carbon 4 equiv. = 24, and oxygen 4 = 32, hydrogen 2 = 58, the equiv. of the acid.†

(f.) *Destructive distillation affords the usual products of vegetable decomposition, and also an acid*, supposed to be a peculiar one; it is called the *pyro-citric*, but if a distinct acid, it is not important.‡

IV. *USES*.—*Tartaric acid is carried to sea as an antidote to scurvy*; it affords an excellent substitute for lemonade; it is necessary only to dissolve it in about 19 parts of water with sufficient sugar, and add the essential oil of lemons. It may be mixed, in the proportion of half an ounce with one pound of sugar, and this may be essenced by 5 or 6 drops of oil of lemons on a lump of sugar.

It was, many years ago, suggested by Fourcroy, that the juice of limes and lemons might, in the West Indies, be saturated with lime or chalk, and then exported to Europe for decomposition by sulphuric acid; this is now done with advantage.

Citric acid is often employed in making the effervescing mixture, with carbonate of potassa or soda. It removes iron stains in the same manner as oxalic acid. It is used by dyers, to enliven the color of the safflower, and to produce a fine red with tin and cochineal, especially for silk and morocco. Like tartaric acid, it whitens and hardens tallow. As the tartaric acid is cheaper than the citric, it is sometimes used to adulterate it, and may be discovered, by adding carbonate of potassa, which, if tartaric acid be present, will precipitate cream of tartar.

* I have one nearly an inch square, formed in London, (July 1805,) which remains unchanged after twenty five years; the acid in the entire solution, placed in Mr. Accum's garret and forgotten, was found to have been absorbed into a single crystal, doubtless at the expense of many smaller ones, in the manner pointed out by Dr. Wollaston, (Faraday's Chem. Manip. p. 253.) In general, great quantities of fluids are necessary to produce large and fine crystals, according to the method of Mr. Dizé in Paris.

† For different views, see Henry, 11th edition, Vol. ii, p. 231, and Phil. Trans. 1812; also Gray's Operative Chemist.

‡ See Henry, Vol. ii, p. 233.

	Equiv. of base.	Equiv. of acid.	Base.	Acid.	Equiv.
Oxalate contains	1	+	1 = 48	+	36 = 84
Bin-oxalate,	1	+	2 = 48	+	72 = 120
Quadroxalate,	1	+	4 = 48	+	144 = 192 (H.)

IV. OXALATE OF SODA.

(a.) *Formed synthetically.*(b.) *Composition.*—Base 1 equiv. 32 + 1 of acid, 36 = 68 its equivalent; * 100 of soda require 112.5 acid, and as it forms a bin-oxalate, twice as much acid = 225 parts are required in that salt; 1 equiv. base = 32 + 2 of acid = 72 = 104, its equiv.; there is no quadroxalate.

V. OXALATE OF AMMONIA.

(a.) *Formed synthetically.*(b.) *Crytallizes* in long transparent prisms; taste bitter.

(c.) Soluble at 60° in the ratio of 45 grains to 1000 of water; in hot water very soluble, and a saturated solution, on cooling, deposits crystals.

(d.) *Composition.*—Ammonia 1 equiv. 17 + 1 of acid, 36 = 53 the equivalent of the anhydrous salt, and in the crystals there are 2 equiv. of water 18 = 71; there is a bin-oxalate, not so soluble as the oxalate. It is a very useful reagent, especially in detecting lime, and is preferred to oxalic acid, because the latter, by setting free a mineral acid, might cause the resolution of the oxalate of lime, while the acid would be engaged by the ammonia, if the oxalate of that base were used.

VI. OXALATE OF LIME.

(a.) *Formed, between oxalic acid or any soluble oxalate, and lime water, or any soluble calcareous salt;* turns syrup of violets green.(b.) *It is a white powder, insoluble in water, but, when recently precipitated, it is very soluble in nitric and muriatic acids;* if, in any water, which we could examine for lime, by means of oxalic acid or a soluble oxalate, nitric or muriatic acid is present in a free state, they must be neutralized before the application of the test; thus, oxalic acid and lime become tests of each other's presence.(c.) *Decomposed by carbonate of potassa.*(d.) *Composition.*—Lime 1 equiv. 28 + acid 1 equiv. 36 = 64 the equiv. of the salt; per cent. lime 43.75 + acid 56.25 = 100.*If slowly dried, it retains four, if rapidly, six equivalents of water, and it is anhydrous, after being heated to 560° F. which temperature it sustains without decomposition. There is no bin-oxalate. This salt is the basis of the mulberry calculus.*

VII. OXALATE OF BARYTA AND OXALATE OF STRONTIA have nothing interesting, except that the bin-oxalate of baryta is soluble, while the

* The water, contained in the crystals, is not in equivalent proportion and is neglected.

oxalate is nearly insoluble; the latter is converted into the former, by the addition of acid, and its crystals are decomposed, by mere solution in water.

VIII. *OXALATE OF MAGNESIA, formed by mingling sulphate of magnesia and oxalate of ammonia*; if the sulphate has been moderately diluted, with cold water, it is not precipitated until it is heated, although after it has fallen, it is insoluble; as lime is instantly precipitated, this affords the best method known of separating these earths. Among the metallic oxalates, some, as those of nickel and cobalt, afford a pure metal, by ignition.

IX. *The oxalate of lead, formed by oxalic acid and acetate or nitrate of the metal, detonates, by being heated in a tube with bits of potassium.**

X. *The oxalate of mercury, produced in the same manner, detonates by heat, and was formerly supposed to enter into the constitution of Howard's fulminating mercury.* Oxalate or bin-oxalate of potassa and antimony, heated together in a covered crucible, afford an alloy of potassium and antimony. Per-oxalate of copper, digested with oxalate of ammonia, affords crystals that detonate by a sudden heat.

II. TARTARIC ACID.

I. NAME AND HISTORY.

Name, from the crude tartar of wine, or from the salt that is purified from it, (cream of tartar,) from which this acid is extracted. Discovered by Scheele in 1770.† It exists in several acidulous fruits‡ but always in combination with lime or potassa. *We always extract it from combination*; it is never formed synthetically.

II. *PROCESS,|| by decomposing the bitartrate of potassa, by chalk.* Taking the proportions by the equivalents, they are as follows.§

* H. and Phil. Mag. 1827.

† His first recorded discovery.

‡ Found in the tamarind, in balm, *Carduus benedictus*, roots of resharrow, germander and sage; sumach is quoted in foreign books as containing tartaric acid, but I am reminded by Prof. Tully, that the American *Rhus glabra* affords malic acid, and that this is probably the fact with all the other American acidulous sumachs. —Ann. Lye. N. York, Vol. 1, p. 42.—I. Cozzens.

|| Or, 100 parts of cream of tartar, 26 1-2 to 30 chalk in 8 or 10 times as much water; add the chalk by portions, when the effervescence ceases, add to the clear liquor a solution of nitrate or muriate of lime, so long as a precipitate falls, wash it and then double as much sulphuric acid as chalk must be added to the tartrate of lime diffused in water, and after 24 hours, the liquor may be examined for sulphuric acid by adding acetate of lead; if the precipitate is only tartrate of lead it will be entirely soluble in diluted nitric acid; if any thing remains, it is sulphate of lead, indicating an excess of sulphuric acid which may be saturated by more chalk, or if the tartrate of lime has not all been decomposed, more sulphuric acid may be added. A little excess of sulphuric acid does no harm, but much would decompose the tartaric acid.

Dr. Henry thinks, that no advantage is gained by substituting quick lime for chalk, for although more of the cream of tartar is decomposed, the liberated potassa dissolves the tartrate of lime and thus prevents its precipitation. With chalk we remove only one equivalent of tartaric acid.—Henry and A. A. Hayes. § Turner.

Powder of cream of tartar (bitartrate of potassa) 198 parts, or one equivalent, intimately mixed with 50, or one equiv. of chalk; throw the mixture, by portions, into 10 parts of boiling water; carbonic acid escapes, with effervescence, and 1 equiv. of tartrate of lime falls, and one of soluble tartrate of potassa remains in solution;* the precipitate is washed, and then diffused through a moderate portion of water, containing one equiv. of sulphuric acid, 49; digestion liberates the tartaric acid, and after the separation of the sulphate of lime by the filter and due evaporation, the acid is obtained in crystals.

III. PROPERTIES.

(a.) *Taste very acid*, setting the teeth on edge, but when diluted, it is agreeable; *reddens the vegetable blues*.

(b.) *Crystallizes in tables or prisms*;† primitive form a right rhombic prism; sp. gr. 1.59.

(c.) *Soluble in 5 or 6 parts of water at 60°*, and in much less of boiling water, a saturated solution, sp. gr. 1.230, becomes mouldy on the surface by keeping; soluble in alcohol.

(d.) By strong nitric acid, converted into oxalic.

(e.) *Does not precipitate lime from the mineral acids*, but separates it from the vegetable; it precipitates baryta and strontia.

(f.) *Composition*.—By the researches of the most distinguished analysts, it appears, that *this acid contains about two thirds of its weight of oxygen; from one quarter to one third of carbon, and a small portion of hydrogen*. Dr. Henry gives, as the most probable

constitution,	Carbon	4 equiv.	24	36.36
	Oxygen	5	40	60.61
	Hydrogen	2	“	23.03

66 100.—And the crystals

consist of anhydrous acid 1 equiv. 66 + 1 water 9 = 75; per cent. 88.16 acid + 11.84 water.‡

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I. PROCESS.

(a.) *By saturating cream of tartar*, 18 parts, with sub-carbonate of soda, 18.

II. PROPERTIES.

(a.) *The crystals are often large and very beautiful*; form prismatic, or rhomboidal prisms, with 10 or 12 sides.

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III. USES.—*A valuable medicine.*

The cream of tartar is so prone to combine with an additional base, that it often acts as a simple acid, and dissolves oxides that are insoluble in the mineral acids, and even in the tartaric.†

4. TARTRATE OF SODA.—It has been already mentioned, as being formed, when the soda powders are mixed; carbonate of soda is better adapted than carbonate of potassa to that use, because it is less prone to form an insoluble bi-salt. The crystals of tartrate of soda are fine needles.

5. TARTRATE OF AMMONIA is formed synthetically; bitter, very soluble; forms an insoluble bi-tartrate.

6. EARTHY TARTRATES.—The tartrate of lime is produced, as already mentioned, in the process for tartaric acid; it has no other use.

* From the apothecary by whom, and the place at which, this salt was first formed.
† Ann. de Ch. et de Ph. Vol. III, p. 281, and H.

The other earthy tartrates are formed, in general, by double exchange, between the tartrate of potassa and a soluble salt of the earth.

7. METALLIC TARTRATES.—That of antimony and potassa is the only important one, (see antimony p. 212.)

The tartrate of lead, formed between acetate of lead and tartaric acid or tartrate of potassa, is a white powder, and when warmed in a tube and poured out into the air it is a *pyrophorus*.

Tartrate of mercury is an insoluble white powder; a triple compound is formed between 6 parts of cream of tartar and 1 oxide of mercury by boiling.

III. CITRIC ACID.

I. NAME, from *Citrus*, the lemon or orange, which contains it in abundance; *discovered by Mr. Scheele*, of Sweden.

II. PROCESS.*

(a.) *Lime or lemon juice is neutralized by chalk, and the citrate of lime is decomposed by sulphuric acid.*

(b.) Saturate the expressed juice by powdered chalk,† with agitation; after subsidence of the solid citrate of lime decant the water, add more, repeatedly, till there is no taste or color in the fluid.

(c.) To the solid citrate,‡ constantly stirred, add as much sulphuric acid, of a density not far from 1.85, diluted with 10 parts of water; stir the mixture, occasionally, for 24 hours; let the sulphate of lime subside; add water, till it comes off tasteless; mix the liquors,§ and evaporate to $\frac{1}{4}$, and more sulphate of lime will fall; evaporate again to the density of a syrup, and brown crystals will form, which are purified by repeated solutions and crystallizations.

III. PROPERTIES.

(a.) *Crystallizes in large rhomboidal tables* or prisms; transparent and beautiful; primitive form, a right rhombic prism.

* As citric acid has become an important article of commerce, much attention is now paid to the details of the manufacture, a full account of which may be found in Parkes' Chemical Essays, and in the 46th Vol. of the Phil. Mag. See also Henry's Chem. 11th edition, Vol. II, p. 228.

† According to Dr. Henry's experience, 6 or 8 oz. of chalk will saturate a wine gallon of lemon juice, and in 1 gallon, he has found even 12 oz. of solid citric acid, but it averages about 6 or 8 oz. to 1 gallon; for a method of estimating the proportion with sufficient accuracy, see Henry's Chem. Vol. II, p. 229, 11th edition.

‡ The equivalents are dry citrate of lime, 86, + 49 of strong sulphuric acid diluted with 10 of water. In general, 90 parts of lemon juice (94 Proust,) require 4 parts of chalk for saturation, which produce 6 parts, (7 1-2 Proust,) of citrate of lime, and 18 parts (20 Proust,) of sulphuric acid are necessary for their decomposition.

§ They may contain a little sulphuric acid and mucilage; the former is detected by acetate of lead, and may be neutralized by more citrate of lime; but a little does no harm, as the citric acid crystallizes and leaves the sulphuric, and also the mucilage. If there is lime in excess, the citric acid will not crystallize.

(b.) *Crystals, permanent* in the air*; lose about 7 pr. ct. by being heated, to the point just below decomposition; *endure all climates and vicissitudes of weather, unchanged*, but the aqueous solution, like those of most vegetable bodies, is slowly decomposed by keeping.

(c.) *Taste very acid*, but agreeable, and *not corrosive*; in solution with water, it is *grateful*; *reddens the vegetable blues*; soluble in $1\frac{1}{2}$ part of cold water, and in half its weight of boiling water.

(d.) *Nitric acid*, 3 parts, *converts it into the oxalic*, half a part, and by increasing the proportion of the nitric, it is essentially converted into the acetic acid.

(e.) *Composition*.—The most eminent chemists have obtained different proportions; but the most probable constitution, deduced from the experiments of Thomson and Berzelius, appears to be, carbon 4 equiv. = 24, and oxygen 4 = 32, hydrogen 2 = 58, the equiv. of the acid.†

(f.) *Destructive distillation affords the usual products of vegetable decomposition, and also an acid*, supposed to be a peculiar one; it is called the *pyro-citric*, but if a distinct acid, it is not important.‡

IV. *USES*.—*Tartaric acid is carried to sea as an antidote to scurvy*; it affords an excellent substitute for lemonade; it is necessary only to dissolve it in about 19 parts of water with sufficient sugar, and add the essential oil of lemons. It may be mixed, in the proportion of half an ounce with one pound of sugar, and this may be essenced by 5 or 6 drops of oil of lemons on a lump of sugar.

It was, many years ago, suggested by Fourcroy, that the juice of limes and lemons might, in the West Indies, be saturated with lime or chalk, and then exported to Europe for decomposition by sulphuric acid; this is now done with advantage.

Citric acid is often employed in making the effervescing mixture, with carbonate of potassa or soda. It removes iron stains in the same manner as oxalic acid. It is used by dyers, to enliven the color of the safflower, and to produce a fine red with tin and cochineal, especially for silk and morocco. Like tartaric acid, it whitens and hardens tallow. As the tartaric acid is cheaper than the citric, it is sometimes used to adulterate it, and may be discovered, by adding carbonate of potassa, which, if tartaric acid be present, will precipitate cream of tartar.

* I have one nearly an inch square, formed in London, (July 1805,) which remains unchanged after twenty five years; the acid in the entire solution, placed in Mr. Accum's garret and forgotten, was found to have been absorbed into a single crystal, doubtless at the expense of many smaller ones, in the manner pointed out by Dr. Wollaston, (Faraday's Chem. Manip. p. 253.) In general, great quantities of fluids are necessary to produce large and fine crystals, according to the method of Mr. Dizé in Paris.

† For different views, see Henry, 11th edition, Vol. 11, p. 231, and Phil. Trans. 1812; also Gray's Operative Chemist.

‡ See Henry, Vol. 11, p. 233.

tate in cold water ; it is sanguinarina, combined with extractive and coloring matter, and mixed with some earths. Dissolve the soluble part in warm alcohol and wash with the same ; distil the clear fluid from a glass retort placed in a vapor bath ; when the solution becomes turbid by concentration, it must be decanted, while hot, into cylindrical vessels, one half filled with cold pure water ; the alkali is precipitated in the form of a yellowish white bulky powder, it is mixed with a portion of a substance insoluble in diluted acids and resembling resin ; by dissolving the soluble part in muriatic acid with 10 of water, precipitating by ammonia and treating as above, the alkali is obtained pure. It should be washed and collected in covered vessels.

III. PROPERTIES.

(a.) It usually appears in the form of a *soft white powder* ; by the spontaneous evaporation of an alcoholic solution, it *may be obtained in masses*, which exhibit a crystalline structure ; possesses no odor, taste bitter, then acid, but less so than its salts.

(b.) *Renders blue colors green, and changes yellow to brown* ; dissolves in most acids and *forms* with them *neutral salts of a red color*, a character peculiar to the alkali. *In a solution of potassa it dissolves* and forms a milky compound, from which *acids*, cautiously added, *precipitate the alkali* ; exposed to the atmosphere, while moist, it absorbs carbonic acid and becomes of a buff color ; soluble in ether and left unchanged by evaporation ; but slightly soluble in water.

(c.) *When heated, it melts* ; on cooling, a transparent, brown, brittle substance remains ; at a higher temperature it is decomposed.

(d.) *The nitrate is formed by double exchange* ; it precipitates, and may be washed in water containing a few drops of nitric acid ; while moist, it is a bulky red powder, but in drying, becomes a reddish brown substance like wax ; soluble in water, solution light red.

(e.) *Sulphate* ; *formed by neutralizing dilute sulphuric acid with the moist alkali*, a beautiful red solution is obtained ; it is more soluble than the nitrate.

(f.) *Muriate* ; *by dissolving the moist alkali in warm muriatic acid*, and evaporating, till a pellicle appears, the whole, on cooling, becomes an imperfectly crystallized mass ; color fine crimson,* very soluble in water ; the solution is decomposed by alkalies ; soluble in alcohol, and is perhaps the best form for medical exhibition.

(g.) *Carbonate* ; *it is of a pale red color*, slightly soluble in water, soluble in an excess of carbonic acid : bi-carbonates do not precipitate the alkali from dilute solutions.

* The color of the native root is due to the malate of sanguinarina, its brightness being clouded by other principles ; the purer the alkali, the brighter are its salts.—
A. A. H. N. B. Printed after the note on page 505.

(h.) *Tartrate*; very soluble, solution of a red color, taste very acrid: crystals of a deep crimson.

(i.) *The oxalate is of a splendid scarlet.**

(j.) *The alkali exists in the root combined with an acid*, the properties of which resemble those of the malic; the malate is slightly soluble in water; very soluble in alcohol.

(k.) *The salts are inodorous, but their powder produces great irritation in the nostrils.*

(l.) They are all precipitated by infusion of galls.

(m.) *Decomposed by alkalies and alkaline earths*; the sanguinarine falls, unaltered, from its union with a dilute acid, but altered from a strong acid; it retains a portion both of the acid and alkali.

(n.) The color of the salts of sanguinarine is attributed to a combination between acids and the alkali.

Its composition has not been ascertained; but Dr. Tully has proved, that the medicinal virtues of blood-root reside in this principle, and that they are not impaired by combination with acids. It is medicinally deobstruent, acrid-narcotic and emetic.†

XVI. PICROTOXIA.

I. ORIGIN AND NAME.—*This is the bitter and poisonous principle of the Cocculus indicus*, the berries of *Menispermum Cocculus*, and although it has received a name, in analogy with those of the vegetable alkalies, it appears not to be entitled to that rank, as it does not act like an alkali by neutralizing acids; as however, it is not without resemblance to vegeto-alkaline bodies, it may be allowed to fall into their train, without being regarded as strictly, one of them. *The name means a bitter poison*, and the opinion of its nature, first proposed by Boullay,‡ has been sustained by the more recent examination of Casaseca.§

II. PREPARATION.

(a.) *Ammonia, in excess, precipitates a white granular crystalline powder*, from a strong infusion of the seeds; this precipitate, after being washed with cold water, is partially dissolved in alcohol, without imparting color, and silky needles are obtained by spontaneous evaporation.

* Obtained by Dr. Tully.

† I owe the materials for this account of sanguinarine to a MS. communication from Mr. A. A. Hayes, and another from Prof. Wm. Tully. The alkali is supposed to have the power of developing color, by combining with acids, but as the color resembles that of the root, it may need farther investigation, to ascertain whether any of the natural coloring matter remains with the alkali, after its extraction, or whether, as suggested by a correspondent, some vegetable acid enters into the composition of these salts.

‡ Thesis Fac. Scien. 1818. The fruit is the produce of two species which are now called *Cocculus suberosus* and *Cocculus Plukenetii*, by Prof. DeCandolle. If *Menispermum Cocculus* can be considered the name of any thing, it belongs to two distinct plants to which the above names are now appropriated.—Prof. Tully.

§ Vol. xxx, p. 307, 1826.

(b.) An alcoholic solution from the seeds, gives the pure precipitate by the aid of magnesia; a grayish powder falls, which, being lixiviated with alcohol, affords white crystals.

(c.) To the filtered decoction of the berries, add acetate of lead, till precipitation ceases; filter and evaporate to the consistence of an extract; dissolve in alcohol, sp. gr. 0.817, and evaporate to dryness; after repeated solutions and evaporations, the substance becomes equally soluble in alcohol and in water, and the latter, by agitation, removes the coloring matter; crystals of picROTOXIA now fall, and may be washed with a little alcohol.*

II. PROPERTIES.

(a.) *Crystals, prisms of four sides; white; disgustingly bitter; inodorous.*

(b.) *Soluble in 25 parts of boiling water, and one half falls on cooling; no known agent precipitates the picROTOXIA from its aqueous solution.*

(c.) *Alcohol* sp. gr. .810, *dissolves* $\frac{1}{2}$, and *ether* sp. gr. .700, $\frac{2}{3}$ of its weight; from the alcoholic solution, water precipitates a portion, which more water dissolves.

(d.) *Decomposed and charred, by strong sulphuric acid; dissolved in the dilute sulphuric acid, which however, it does not saturate in the least; soluble, also, in acetic acid† and is precipitated by carbonate of potassa; soluble in weak caustic alkalies, and in olive, almond, and turpentine oil.*

(e.) *Decomposed by heat; burns without flame and smells like a resin; its exact constitution and proportions are unknown.*

(f.) *Fatal to life; ten grains, being given in a crumb of bread, to a young dog of common strength, the animal died in forty five minutes, in violent convulsions.*

Remarks.—It appears that the substance, insoluble in alcohol, contains animal and coloring matter, iron, silica, sulphate and muriate of potassa, phosphate of lime,‡ &c.

CAFFEÆ.—*It appears doubtful whether this is an alkali.* It was discovered by Robiquet, when he was searching for quinia in coffee, for coffee is of the same family with cinchona, and both possess febrifuge properties. The evaporated aqueous extract is treated with calcined magnesia, and the *caffæa crystallizes in arborescent forms*, nearly colorless and transparent; being redissolved in alcohol or boiling water, it falls, on cooling, in silky crystals like amianthus.§ *It is white, slightly soluble and crystalline. It has not the power of saturating acids.||*

* Ure's Dictionary. † With the acetic acid, it forms a crystallizable compound.

‡ The *menispermic acid*, formerly named as existing in the *Cocculus indicus*, is a mixture of sulphuric acid and organic matter.

§ See another and much longer process by Pelletier, Ann. Phil. Vol. xii, p. 355, Nov. 1826.

|| Ann. de Ch. et de Ph. Vol. xxiv, p. 183.

Its *composition* is carbon, 46.51, nitrogen, 21.54, oxygen, 27.14, hydrogen, 4.81, = 100. It contains more nitrogen than most animal bodies, and still is not, like them, disposed to putrefaction.*

The hemlock, *Conium maculatum*, is said to afford another alkali, half a grain of which killed a rabbit.†

OLIVILE,‡ extracted by alcohol, from the gum of the olive tree; it is in powder or in needles; inodorous; taste bitter, sweet and aromatic.

CATHARTIN,§ the medicinal principle of senna.

It appears, that there is no exclusive bitter principle, as the bitterness of plants depends on various things, and is different in the hop, in the nux vomica, in bark, in opium, &c.

Extract seems not to be a distinct principle, although the word is still used. It is now regarded as modified tannin.|| The hot aqueous solution grows turbid in cooling; a hot infusion of galls or of bark, passes turbid through the filter, apparently from absorbing oxygen, and by repeated solutions and evaporations, it becomes insoluble. It would be well if the word were dropped, although, as it is not yet discarded by chemists, I have found it difficult to avoid using it, occasionally, in the preceding pages.

SEC. XVIII.—OTHER VEGETABLE PRINCIPLES OR PRODUCTS, some of them doubtful.

1. ASPARAGIN,¶ in the juice of asparagus, with an acid called the aspartic; in the *Althea officinalis* or marsh mallow, with malic acid, and in the juice of fresh liquorice** root and in comfrey.

The crystals fall, spontaneously, from asparagus juice;†† they are white, form rectangular octahedra, or prisms of six sides, or right rhombic prisms; taste, cool and nauseous; it is neither acid or alkaline. The aspartic acid crystallizes in square prisms, turns starch into sugar and forms numerous salts with the bases.‡‡ Both it and the asparagin appear to contain nitrogen, as ammonia is obtained by their decomposition.

2. ULMIN.—Obtained by Klaproth in 1802, from Palermo, being an exudation from a species of elm. Elm bark, acted on by hot

* But damaged coffee is offensive, and its exhalations are commonly thought to be unhealthy.

† Several new vegetable alkalies were announced, last year, by Dr. C. C. Conwell, of Philadelphia, for an account of which see his printed dissertation on vegetable chemistry.

‡ Ann. of Philos. Vol. xli, p. 33; Jour. de Phar. Vol. li, p. 337; Thén. Vol. iv, p. 253.

§ Ann. de Chim. et de Phys. Vol. xvi, p. 16.

|| Ann. de Chim. et de Phys. Vol. xxvii, p. 384.

¶ Ann. de Chim. Vol. lvii, p. 88; Ann. de Chim. et de Phys. Vol. xxxvii, p. 81.

** It appears not to be found in dried liquorice.

†† Heated to coagulate albumen, and left for 15 or 20 days.

‡‡ Ann. de Chim. et de Phys. Vol. xl, p. 309.

alcohol and cold water, and then by an aqueous solution of an alkaline carbonate, yields ulmin, when an acid is added. It greatly resembles gum; solid, hard, black, lustrous; soluble in water, but does not form a paste; precipitated by alcohol, in which it is rendered soluble by nitric acid and chlorine; it appears then to become resinous by acquiring oxygen. It exists in the bark of most trees, and exudes from many; it is tasteless; not precipitated by tannin, gelatine or acids; ammonia and oxygen convert gallic acid into ulmin;* composed of 12 carbon, 1 hydrogen, and 16 oxygen.

3. **DAHLINE**—*this product is from the Dahlia,† and is found in the Jerusalem artichoke*; it has great analogy with starch, particularly in becoming sugar by the action of sulphuric acid; it also resembles inulin. It is white, inodorous, tasteless and more soluble in hot than in cold water. For the processes‡ and other particulars, see the authorities cited below.§ The Jerusalem artichoke is nutritious, principally in consequence of this principle or of inulin, both of which are probably varieties of secula. Dahline, on being evaporated, forms a granulated mass, and is heavier than starch.

4. **INULIN**—*from the root of elecampane, Inula Helenium*. The extract from the hot infusion of elecampane roots is washed with cold water which deposits the inulin; it falls also, spontaneously, from the hot infusion, as it cools. Like starch, it is insoluble, in cold but soluble in hot water; unlike it, it falls as the fluid cools, and it does not give a blue with iodine, but a perishable greenish yellow; its insolubility in cold water distinguishes it from gum, and nitric acid does not convert it into the mucous acid; its aqueous solution is precipitated by alcohol. It is found in *Colchicum autumnale*,|| in the *Anthemis Pyrethrum*,¶ in the *Angelica Archangelica*, and is said to exist in the gall nut.**

5. **LEGUMINE**—*extracted from the pulp of ripe peas*; after the deposition of starch, it falls in scales which become white by the action of alcohol, and this dissolves a green matter like chlorophyllin. Vegetable acids dissolve legumine, but the mineral acids form with it insoluble compounds, which are dissolved by boiling with more of the same acid. Both its aqueous and alkaline solutions may be made to froth, and may be blown into bubbles like soap. Its solution in weak

* Ann. de Chim. et de Phys. Vol. xxiv, p. 335.

† Originally named after Georges, a Petersburg professor, and called Georgina or Georgia by all the systematical works on botany.—w. r.

‡ The process is concisely this. The infusion of the pulp of the Dahlia is boiled with one twentieth of chalk, and after evaporation is treated with charcoal and white of egg; the filtered and evaporated fluid deposits Dahline on cooling.

§ Ann. de Chim. et de Phys. Vol. xxiv, p. 210; Id. Vol. xxx, p. 358; also Henry, Vol. ii, p. 354, 11th Ed. and Ure's Dict. p. 384.

|| It produces a blue with iodine, but owing to starch with which it is combined.

¶ The pyrethrum contains 33 per cent. and 11 of gum.

** Ann. de Chim. et de Phys. xiv, p. 52, and Vol. viii, p. 102.

acids, gives, with sulphate of lime, a dense coagulum, which is supposed to explain why peas are hardened by boiling with gypseous water. Peas, by Braconnot's analysis, contain 18.40 per cent. of legumine, with 42.58 starch, 8 water, 4 pectic acid, animalized matter 8, &c. and beans are almost identical in their composition.*

6. *FUNGIN is the fleshy part of the mushroom*, after alcohol and alkaline water have removed every thing soluble in them. It is white, insipid, soft, slightly elastic, highly nutritious and innocuous; very combustible and emits a panary smell; it yields ammonia by destructive distillation; nitrogen is evolved by nitric acid, and it putrefies with an animal odor, and for these various reasons, it appears much assimilated to animal matter.†

7. *NICOTIN—from tobacco, Nicotiana Tabacum*. The juice of tobacco is repeatedly evaporated and poured off from a gritty powder as often as it falls, and is then digested with alcohol which is gently distilled to dryness, and this is repeated from the residuum dissolved in water; potassa removes acetic and malic acids, and by distilling again to dryness, and repeating the solution of the residuum and the distillation, the nicotin passes into the receiver and is obtained in a colorless solution, smelling like tobacco, and causing sneezing; it is acrid, and a powerful narcotic poison; it resembles some volatile oils.‡

8. *PIPERIN, from black pepper, Piper nigrum*.

Pepper is digested in alcohol, and the residuum of its evaporation, which, after being washed with warm water, is green, and has a burning taste, is again dissolved in alcohol, which, spontaneously, deposits crystals on standing; they are purified, by repeated solutions and crystallizations.§

One gallon of alcohol is digested, for ten days, on 1 lb. of black pepper; half is distilled off; muriatic acid is added to dissolve the piperine, and water to separate resin and oil; decompose the concentrated muriate by potassa, and the piperine precipitates in crystals, colored yellow by the oil.|| If pure, they are white, inodorous and insipid, but with the resin that remains in the crystals they are hot

* Ann. de Chim. et de Phys. Vol. xxxiv, p. 84.

† Ann. de Chim. Vol. lxxix, p. 267, and Hen. Vol. ii, p. 856, 11th Ed.

‡ Ann. de Chim. Vol. lxxi, p. 139, and Hen. Vol. ii, p. 858, 11th Ed. Dr. Conwell, Am. Jour. Vol. xvii, p. 369, states that the poisonous property of tobacco is in a yellow oil having the smell and taste of the plant, and he finds a new vegetable alkali which he calls nicotia. The empyreumatic oil of tobacco, disengaged in smoking, is doubtless nicotin modified, and perhaps rendered more noxious by the heat; (See note, p. 440, of this Vol.) As a source of refreshment and pleasure to man, tobacco ought to be universally proscribed; it should be retained only as a means of destroying insects and vermin, and as a medicine, which, in its internal use, is however, so violent and dangerous, that the proper occasions for employing it must be few and far between.

§ Pelletier, Ann. de Ch. et de Ph. Vol. xvi, p. 337.

|| Mr. G. W. Carpenter, Am. Jour. Vol. 13, p. 334: the oil may be entirely removed by great care in the precipitation, but it does no harm and it is not worth while to remove it.

and acrimonious and have, to a degree, the smell of pepper. The crystals are prisms of 4 sides, very soluble in alcohol and less so in ether;* they assume a feathery form, when falling from a solution in acetic acid. The activity of the pepper appears to reside in the oil and resin, and pure piperin is an inactive substance.† There are two oils of pepper, one volatile and aromatic, the other fixed and pungent.

9. **DRACINE**, *the coloring matter of the balsam, called Dragon's blood.* The precipitate from the alcoholic solution by water is washed with that fluid, acidulated with $\frac{1}{10}$ of sulphuric acid and then with water alone; the dracine is of a fine red color; its sulphate is made, by adding sulphuric acid, diluted with alcohol, to the tincture of dracine; cold water and a little heat precipitate the sulphate, which, after thorough washing, is dissolved in hot water; alkalies redden the solution most sensibly, and it is an excellent test of them; acids render dracine yellow; even the small portion of carbonate of lime, in the filter, will redden sulphate of dracine.‡

10. **POLYCHROITE**, § *the yellow coloring matter of saffron*, extracted by alcohol; from πολυς, many, and χροά, color, on account of the varied colors which it produces with acids, blue with the sulphuric, and green with the nitric.

11. **HÆMATIN**, *the coloring matter of log wood, Hamatoxylon Campechianum*, extracted by alcohol from the inspissated aqueous extract; the tincture, evaporated and then diluted with water, deposits crystals of a reddish white, brilliant, when seen by a magnifier, acrid and bitter.

Boiling water dissolves them and forms an orange yellow solution. || Away from the air, potassa turns it blue, but oxygen restores the yellow; this alkaline solution deprives a limited portion of air of its oxygen. ¶

12. **COLOCYNTINE**, ** *the bitter principle of the colocynth*, extracted by alcohol.

13. **RHEIN**, *from rhubarb*, extracted by nitric acid and also by ether; it is yellow, has little odor, and is slightly bitter; its solutions in ether, alcohol and water, are reddened by alkalies, and made yellow by acids. ††

* Mr. Carpenter obtained them in larger crystals, from solution in ether.

† See Mr. Carpenter's memoir for the medical effects of piperin.

‡ Phil. Mag. and Ann. Vol. II. p. 394, and Bib. Univ. Vol. XI. p. 157.

§ Ann. de Ch. et de Ph. Vol. LXXX, p. 188. Jour. de Phar. Vol. VII, p. 397. Thénard, Vol. IV, p. 192.

|| Ann. de Ch. Vol. LXXXI, p. 128, and Thénard, Vol. IV, p. 181.

¶ Eng. Quart. Jour. Vol. XX, p. 389.

** Eng. Quart. Jour. Vol. XVIII, p. 400. Jour. de Phar. for 1824, p. 416.

†† Ann. de Ch. et de Ph. Vol. XXXIV, p. 190.

14. **ZANTHOPICRITE**, *from the bark of the Zanthoxylum of the Antilles*; extracted by alcohol and water, and by evaporation, silky, divergent needle crystals fall; they are soluble in alcohol and water, but not in ether; the precipitate by solution of gold, is soluble in alcohol and in liquid ammonia.

15. **BASSORIN***—It was named *from Bassora in the East*. (See p. 396, note, of this volume.) It is closely allied to gum; it is extracted from the gum-resins;† by the successive action of water, alcohol, and ether, in all of which it is insoluble, but it swells very much in water and becomes buoyant; does not however dissolve in either boiling or cold water, but hot water, sharpened by nitric or muriatic acid, dissolves it entirely. From the concentrated solution, alcohol throws down a substance which has all the properties of gum arabic, and amounts to about $\frac{1}{16}$ of the whole of the bassorin.

16. **POLLENIN**‡—*this is the pulverulent substance on the anthers of flowers*; that of the date seems almost animalized, and it is to this principle, between albumen and gluten, that the term pollenin has been applied. It is yellow, tasteless, and inodorous; insoluble in water, alkalies, alcohol, or oils. In the air it putrefies, smells like cheese, and disengages ammonia. It is very combustible; and the vivid flash, produced in the blaze of a candle, by the sporæ of the *Lycopodium clavatum*, is well known.§

17. **LUPULIN**—*the yellow powder of the hop*, (*Humulus lupulus*), in which reside the bitter principle, the aromatic flavor, and the chief medical virtues of this plant;|| it contains tannin, extract, a bitter principle, wax, and lignin. Lupulin is found in all parts of the plant, but chiefly in the female flowers.

18. **MEDULLIN**—*the pith of the sun-flower, Helianthus annuus*; it is insoluble in water, ether, alcohol, and oils; soluble in nitric acid; inodorous, tasteless; by destructive distillation, affords ammonia and bronze-colored charcoal.¶

19. **SARCOCOLL**** *from the Penæa Sarcocolla*, an Ethiopian plant.†† It greatly resembles liquorice; its taste is sweet and bitter; *dissolves in alcohol and in water*; with the latter, forms a mucilage which may be used as a paste; it is precipitated by tannin, while gum is not.

* Bulletin de Pharm. Vol. III, p. 56. Thénard, Vol. IV, p. 234, 5th edition.

† Asafoetida, bdellium, sagapenum, euphorbium, &c.

‡ Thomson's Annals, Vol. VII, p. 49. Ure. Thénard. Henry.

§ The lycopodium is quite a distinct substance from the pollen of perfect plants, being indeed the sporæ or minute seeds of the fern.—J. T.

|| First announced by Dr. Ansel Ives of New York, in the Am. Jour. Vol. II, page 802.

¶ Thomson's Chem. Cooper's Am. ed. Vol. IV, p. 146.

** Id. Vol. IV, p. 32.

†† Sarcocoll comes also from Persia, Turkey and India.

SEC. XIX.—SPONTANEOUS CHANGES IN VEGETABLE MATTER

Fermentation.—The changes to which vegetable substances are liable, are usually classed under fermentation and germination. Under fermentation we distinguish the vinous, producing alcohol; the acetous, vinegar; and the putrefactive, ending in decomposition: to which, some add the panary, producing bread, and lastly, the saccharine, generating sugar. The latter may be as well referred to the general laws of vegetable life, since it relates chiefly, if not exclusively, to the conversion of starch or mucilage into sugar.* The chemical changes which produce germination, and which relate to the food and growth of plants, are appropriate subjects of vegetable physiology, but will be briefly mentioned in the sequel.

I. PANARY FERMENTATION.

This has been *already mentioned in connexion with gluten*, and is now named again for the purpose of giving it its proper arrangement, and of stating some additional facts. It is the change which the farinaceous and glutinous substance of flour undergoes in forming bread.

It is well known, that *carbonic acid gas is the agent in raising dough*, and that it is evolved by the reaction of the materials, aided by the ferment.†

It was formerly supposed, that during the fermentation, the gluten and farina in wheat flour, underwent a complete change; but it now‡ appears, that *all the gluten and most of the farina remain unchanged*, about one fourth of the latter being converted into a gummy saccharine matter, and that *alcohol is also produced, at the expense of about five per cent of sugar*, contained in the flour.

Alcohol has been obtained by heating, in a distilling apparatus, the dough, raised by leaven, without yeast; it varied, in different cases, from one to five per cent. and, when rectified by repeated distillations, it burned, and kindled gunpowder.§ Thus it appears, that *the distinction, between the panary and vinous fermentation, is little more than verbal*; if however, the fermentation be carried too far, acetic acid is produced; the bread turns sour, and the quantity of alcohol

* See Turner's and Thénard's Chemistry.

† It used to be said that this gas, as contained in natural or artificial mineral waters, will produce the same effect, and we have been often assured, that at Saratoga and Ballston springs, state of New York, they occasionally raise their bread in this manner; but it is now denied that good bread can be produced in that way; the mechanical raising can be effected by carbonate of ammonia and by the other alkaline carbonates; but the best bread is made with a ferment, and thorough kneading is indispensable.

‡ Colquhoun, in Ann. of Phil. Vol. XII, p. 161.

§ Brewster's Edin. Jour. Vol. VI, p. 361, Graham.

is diminished; the acidity is easily remedied by the alkaline carbonates, as stated p. 416 of this volume.

*When the panary fermentation has ceased, it can be renewed by the addition of sugar, at the expense of which it is probable that the alcohol is formed, and most of the carbonic acid; a part of the latter may come from the yeast, which contains it, or from the other ferments used in families.**

II. VINOUS FERMENTATION.

This process is familiar, in the cases of beer, cider, perry, wine, metheglin, &c.

1. *Sugar, or starch which easily becomes sugar, water, a temperature of 60° or more,† and some substance for a ferment, are necessary for the commencement of this process.‡* Yeast,§ which is the froth of strong beer, or other fermenting alcoholic fluids, will cause fermentation in a solution of four or five parts of sugar, with 20 of water; carbonic acid gas will be disengaged, and the intestine motion which it produces, having ceased, the impurities will subside or float, and farther change will be arrested or proceed afterwards more tardily. A solution of pure sugar, without a ferment, is more prone to become sour than to form spirit.

2. *Many natural juices, containing sugar, mucilage, acids, &c. ferment, spontaneously, without yeast, and are supposed to owe it to gluten contained in them.*

3. *The making of barley consists in a commencement of germination; it is soaked in water, and spread on a floor; the radicle shoots downward and the plumula upward; the change is arrested by heat, and the barley is now saccharine, rather than farinaceous; its infusion in water, qualified by the bitter of the hop or of its lupulin, produces alcohol, by fermentation, and this is blended with sugar, mucilage, and other principles; beer is therefore more prone to become sour than wine.*

4. *It is not indispensable, that farinaceous substances should be, before hand, converted into sugar, in order to produce alcohol; raw*

* Dr. Colquhoun's elaborate and instructive essay, already cited, may be consulted for many important practical and scientific views.

† The process is not rigorously confined to a particular temperature; it cannot go on below 32° F.; it proceeds slowly at 50°, moderately at 60°, rapidly at 70°, too rapidly at 80°.

‡ First accurately examined by Lavoisier, see his Elements of Chemistry.

§ Yeast consists of carbon, hydrogen, oxygen, and nitrogen, and a white deposit collects after fermentation, which resembles gluten, putrefies like it, and affords ammonia by destructive distillation; dried yeast will produce fermentation when applied to a saccharine fluid. Gluten mixed with tartar, will act as a ferment, and so will soft cheese, fibrin, dried albumen, &c. Dr. Hare states that $\frac{1}{1000}$ part of yeast is, when properly managed, sufficient to set fermentation a going.

grain can be made to ferment, and unmalted grain is added, often in large quantities, to that which is malted, for the production of alcohol; potatoes afford it readily without previous germination.*

5. *The presence of the air is not necessary to the continuance of the vinous fermentation*, as it will proceed equally well without it; † still, at least in the juice of the grape, some action of the air seems necessary; ‡ the bottled juice, kept tight and cold, does not ferment, nor do crushed raisins placed in a close glass over mercury, but a single bubble of oxygen gas will cause the fermentation to begin.

The change in the vinous fermentation consists in the conversion of sugar or secula into carbonic acid and alcohol; it is supposed, however, that the secula may become sugar in the process.

6. *Fermented fluids that are agreeable to the taste, still contain sugar unchanged*, and also acids and mucilage, and frequently, carbonic acid.

Most of the acidulous matter of the wines of warm climates is bitartrate of potassa, which; being insoluble in alcohol, is chiefly precipitated in the course of the fermentation. There is also in the juice of the grape, tannin, mucilage, tartrate of lime, common salt and coloring matter, blue or yellow; the tannin, by combining with the gelatine and albumen of glue and whites of eggs, enables them to clarify wine, by entangling the foreign substances. The wines from the currant and gooseberry, contain free acids, the citric and malic, which are soluble in both water and alcohol; they therefore remain acid, unless highly qualified by sugar, and even this is, in time, decomposed to afford more alcohol, and thus the acids again prevail and the wine is sour. Fermentation is prevented, by impregnating the must with sulphurous acid gas or with a sulphite.§

7. *Since intoxication is so readily induced by fermented fluids, it appears singular that the question should have been raised|| whether alcohol is produced by fermentation, or whether it is formed during distillation.* It has however been decided by the experiments of Mr. Brande¶ and Gay-Lussac, that the spirit exists previous to distillation. The former withdrew the acids and color-

* Clement, Ann. de Chim. et de Phys. Vol. v, p. 422.

† Still, vegetable juices, heated to the boiling point and then corked, will remain unfermented; this is the fact with the must or juice of the grape; gooseberry juice sweetened, bottled, and placed for half an hour in a water bath, will preserve the peculiar flavor of the fruit, but, if the fresh juice is exposed, for only a few minutes, to the air, it absorbs oxygen and fermentation begins.

‡ Perhaps to oxygenize a kind of vegeto-animal matter contained in the juice, and thus to convert it into a ferment, supposed to be analogous to yeast.

§ It is common in this country, to impregnate cider barrels in that manner, (Vol. I, p. 317, d.); it is supposed that such substances act by abstracting oxygen; probably also as antiseptics.

|| By Fabroni.

¶ Philosophical Trans. 1811 and 18.

ing matter by sub-acetate of lead,* and the water by sub-carbonate of potassa, when the alcohol floated, in quantity about the same as when it is obtained by distillation. The latter used powdered litharge instead of acetate of lead, and shewed, by obtaining alcohol by a distillation at 59° F. in vacuo, that it existed ready formed in wine and other similar fluids.

Mr. Brande constructed a table of the proportion of alcohol in many different kinds of wine and other liquors, from which the following is compiled.

Wines, &c.	Prop. of Spirit, per cent. by Meas.	Wines, &c.	Prop. of Spirit, per cent. by Meas.
Lissa, average of two,	25.41	Burgundy, average of four,	14.57
Raisins, do. three,	25.12	Hock, do. three,	12.08
Marsala, do. two,	25.09	Champagne, do. four,	12.61
Port, highest,	25.83	Red Hermitage,	12.32
lowest,	19.00	Vin de Grave, average two,	13.37
average of seven,	22.96	Frontignac,	12.79
Madeira, highest,	24.42	Gooseberry,	11.84
lowest,	19.24	Orange, average of six,	11.26
average of four,	22.27	Cider, highest,	9.87
Currant,	20.55	lowest,	5.21
Sherry, average of four,	19.17	Perry, average of four,	7.26
Teneriffe,	19.79	Mead,	7.32
Lisbon and Malaga,	18.94	Ale, Burton,	8.88
Red Madeira, average of		Edinb.	6.20
two,	20.35	Dorchester,	5.56
Cape do. do. three,	20.51	Brown stout,	6.80
Vidonia,	19.25	London porter, average,	4.20
Malaga,	17.26	Small Beer, do.	1.28
Claret, highest,	17.11	Brandy,	53.39
lowest,	12.91	Rum,	53.68
average of four,	15.10	Gin,	51.60
Malmsey Madeira,	16.40	Scotch whiskey,	54.32
Sauterne,	14.22	Irish do.	53.90

8. *As the intoxicating effects of wine appear to be much less, in proportion to the alcohol it contains, than those of distilled spirit, it is probable that the difference arises from the blending of the spirit with other principles present in wines, such as sugar, mucilage, coloring matter, &c.*

The strongest wines appear to contain nearly half as much alcohol as proof spirit, but to such wines alcohol is always added, before they reach the consumer, while the natural wines, such as those of Burgundy, Champagne, Frontignac, &c. contain not more than half as much.

* Goulard's extract.

9. It is well known that *the principal kinds of spirit in commerce are obtained from various substances*, and among them are the following; brandy, from wine; rum, from molasses, diluted and mixed with yeast; gin, from rye, and its flavor is owing to the volatile oil of the juniper berry; whiskey, from rye, wheat and beer; apple brandy, from cider, &c. A spirituous fluid can be obtained from all fruits and from all saccharine juices; even milk affords the koumiss* to the Tartars; alcohol is made from the juice of the sugar maple, from carrots and parsnips, &c. All the fermented undistilled fluids that produce intoxication, owe this effect to one and the same agent, variously diluted and qualified by other principles.

10. *It is not necessary to describe the common process of distillation*;† its principle has been stated at p. 86, Vol. I. It is obvious, that *bottled liquors derive their superiority from the slow fermentation* which they undergo. If they are bottled too soon, that is, before the first rapid fermentation is finished, the bottles explode; if when that has subsided, the liquor is still saccharine, and the fermentation will proceed slowly after the bottling; more alcohol and carbonic acid will be formed; the latter, if the vessel is tight, is retained, and combines with the fluid and water, but produces a pressure sometimes too great for the strength of the bottle, and if not, it causes the liquor to fly when the cork is drawn, and thus it becomes both grateful and salutary. If there is not saccharine matter enough to supply this second fermentation, the fluid becomes acid and is unpalatable. Cider,‡ ale, porter and common beer, are familiar domestic examples. Currants and gooseberries do not contain sugar enough to make a good wine, and it is therefore added to them.

ALCOHOL.

I. HISTORY.—Known, in the fermented fluids, from the remotest antiquity; first distilled as is said, by an Arabian chemist, about nine hundred§ years ago; by others it is said to have been discovered by Arnold de Villeneuve at Montpellier, early in the 14th century.||

II. PROCESS.

1. *By repeated distillations*, sometimes three or four in succession, of any of the spiritous liquors of commerce, drawing off each time $\frac{1}{2}$ or $\frac{2}{3}$; it is called rectified spirit, and is good enough for common purposes; its sp. gr. will be .835 or .840, water at 60° being 1.000; the best that can be obtained by simple distillation is no lighter than .825.

* The koumiss is made from mare's milk, see Aikin's Diet. Vol. ii, p. 103.

† The first product of the distillation of wine is called brandy, (eau de vie,) the second, containing more alcohol, is called spirit; when it has, at least, 85 per cent it is called spirit of wine or alcohol.

‡ Apple juice contains mucilage, malic and acetic acids, but no tartar.

§ Prof. Mussey's discourse before the Medical Society of New Hampshire.

|| Thénard.

2. *By abstracting the water from rectified spirit.*

(a.) *By carbonate of potassa* (pearlshashes,) previously ignited and added while dry.

(b.) *By ignited muriate of lime** in powder, by dry quicklime, or baryta,† or alumina; the alcohol forms a stratum over these substances, which, while water remains, are either dissolved or moistened; the alcohol is drawn off by a syphon, and more of the substance is added to attract the water till it is no longer moistened, and then the spirit is distilled.

(c.) *Potassa, dissolved in alcohol, brings it to a high state*; I have been accustomed to distil off about $\frac{1}{2}$ or $\frac{2}{3}$ in a glass retort or receiver, and then to dissipate the rest in a silver basin.‡

3. *By exudation and evaporation.*

(a.) Alcohol sp. gr. .867, being placed in a bladder and exposed to the air over a sand bath, the water will exude and evaporate until the alcohol becomes of the sp. gr. .817; but it does not appear that very good alcohol is improved in this way.§

(b.) *By evaporation and absorption of the water in a vacuum.* Over a large shallow basin covered with quick lime, is placed another, containing 3 or 4 ounces of common alcohol; they are covered with a low receiver on the plate of an air pump, and a vacuum is formed till the alcohol begins to boil; the vapor of the water will alone be absorbed by the lime, and the water will continue to evaporate, until in about five days it will be all removed.||

The most useful of the above processes, are those under 2, a, b and c. ¶

III. PROPERTIES.

(a.) *Lighter, in proportion as it is better*; as already remarked, the best, obtained by repeated distillation, is of the sp. gr. .825; that from substances attracting water, is sometimes as high as .796 or .792 at 60° F.; if of sp. gr. .917, it contains equal weights of alcohol sp. gr. .796 and water.—H. Proof spirit (usually half and half by volume,) is about .920, but there is much uncertainty in the language of commerce on this subject, as the sp. gr. of the alcohol is not always specified.**

(b.) *Alcohol, supposed to be entirely deprived of water, is called absolute alcohol*; in proportion as it contains more water it is heavier, and thus its specific gravity becomes a test of its strength; it is

* Muriate of lime, after the second application, is liable to form some ether.

† If baryta remains dry in alcohol, it is free from water; otherwise it will slack and fall to powder. ‡ Vol. I, p. 240.

§ Eng. Jour. of Science, Vol. vii, p. 381, and Vol. xviii, p. 180.

|| Edin. Philos. Trans. 1823, and H. and T. As the alcohol is kept down by its own vapor and the water is not thus repressed, this fact favors strongly, Mr. Dalton's view of the indifference of most gases and vapors to each other.

¶ A rough judgment is formed of the goodness of alcohol by burning it on a cotton rag or on gunpowder, both of which it should inflame.

** See Dr. J. W. Webster's Manual, p. 538, Note.

above proof when it is lighter than .920, as it then contains more than half alcohol, and the reverse is, of course, true. It is often interesting to the revenue of various countries, to know the proportion of alcohol in spirit, whose density is ascertained by the hydrometer^{*} or gravimeter, and copious tables have been compiled for this purpose.†

It will be sufficient to mention, in this place, a few examples; pure alcohol at 60° F. is of sp. gr. .796, pure water being 1.000; that of .820, has 9 per cent of water; of .830, 13; of .840, 17; of .851, 21; of .860, 25; of .870, 29; of .880, 34; of .891, 38; of .900, 42; of .920, 51; of .941, 61; of .951, 66; of .970, 77.

(c.) *Alcohol is a non conductor of electricity; it is colorless, transparent, very odorous and penetrating; highly exciting and intoxicating; produces cold by its evaporation*, as may be seen by wetting a thermometer ball with alcohol, and waving it in the air.

(d.) *Volatile*; when of sp. gr. .820, it boils at 176° F.; in *vacuo* at 56°; if of sp. gr. .800, it boils at 173.5°; if .900, at 182°; if .850, at 170°; *the boiling point, therefore, varies with the proportion of water*, but not regularly;§ when agitated with air, the bubbles rise and break more quickly as the alcohol is better.

(e.) *It readily unites with water but with no sensible change of properties*; the mean sp. gr. is increased, the volume diminished, and heat is evolved. 1 vol. of alcohol, + 1 of water at 50°, rise 20°, in temp. and proof spirit and water, 9½°.—H.

(f.) *Very expansible by heat*; its expansion increases as the heat rises, but not very equally, especially as we approach the boiling point; alcohol is therefore less accurate in thermometers than mercury.

(g.) *It is used in thermometers, especially to measure intense cold, as it has never been frozen*;|| in Mr. Walker's experiments with freezing mixtures, it remained fluid at 91° below 0, and when it contains half water it requires 6° below 0 for its congelation.¶

* For the varieties of these instruments, see the books on natural philosophy. See also Dr. Hare's Compendium, p. 85. A delicate vial with a narrow neck, of the capacity of 1000 grs. of distilled water at 60°, reckoning to a mark or scratch on the neck, answers every purpose; the absolute is the specific weight, and calculations are unnecessary.

† See Phil. Trans. 1794, Nich's Jour. 4to. Vol. i, Henry, Vol. ii, p. 370-4, 11th edition, and Ure's Dict. 3d London edition, p. 122.

§ Ann. Philos. N. S. Vol. v. p. 313.

|| Vol. i, p. 59.

¶ The claim of Mr. Hutton, of Edinburgh, as regards the congelation of alcohol has never been admitted, because his process has never been published.—Nicholson's Jour. Vol. xxxiv, p. 165. The late Dr. Murray, appeared at the time, to have believed the fact, (letter to the Author;) but his son treats it as doubtful in the sixth edition of his father's Elements, Vol. ii, p. 554. Mr. Hutton stated that when it froze, it shewed three distinct strata. The first thin, yellowish green, and having a nauseous smell and taste; the second also, thin resembling the other, but agreeable and penetrating; the third much thicker, transparent, insipid, fuming, and with a strong penetrating odor; this last he supposed to be the pure alcohol, and the rest foreign matter.

(h.) *The latent heat of the vapor of alcohol is not quite half that of steam*;* the density of the vapor of pure alcohol is 1.163, air being 1.†

(i.) *Very inflammable*;‡ *kindles at 300°*, and burns without smoke or residuum; a spirit lamp is of great utility in the laboratory, and an elegant source of heat in the parlor; the flame, directed by a stream of oxygen gas upon lime or chalk, gives a most intense light, and is now used for light house and night signals; it is said that it will cast a shadow for many miles; the light is pale when the flame burns merely in the air; strong alcohol is tinged blue, and weaker alcohol, yellow; its flame is colored red by salts of strontia and of lime,§ green by cupreous salts and by boracic acid, &c.

(j.) *The products of the combustion are, exclusively, water and carbonic acid gas*, as may be observed by burning a jet of its vapor in a glass tube or in a bottle;|| the water alone exceeds the weight of the alcohol in the proportion of 136 to 100, because it obtains oxygen from the air; it may be inflamed by the electric spark, and oxygen gas, charged with its vapor, detonates by the same agent.

(k.) *It is, after water, the most general solvent.* It dissolves camphor, manna, balsams, resins, sugar, soap, volatile oils; several vegetable acids, as the oxalic, tartaric, gallic, camphoric and benzoic; castor oil, but not the fixed oils generally; iodine; sulphur; the caustic alkalies, but not their carbonates, nor the pure earths, nor metallic oxides; the vegetable alkalies; the deliquescent salts generally,¶ but not the efflorescent salts, nor those that are insoluble or sparingly soluble in water.—H. and T.

(l.) *Among the salts that are most soluble in alcohol are the alkaline and earthy muriates*, and some of the nitrates; 240 grs. of boiling alcohol** dissolve 17 of muriate of ammonia; 288 of muriate of lime; 1313 of muriate of magnesia;†† 240 of nitrate of alumina; 214 of nitrate of ammonia; 388 of nitrate of lime; 694 of nitrate of magnesia; but the nitrate of potassa is dissolved, only in the proportion of 5 parts, and the nitrate of soda of 23. The dissolving powers of alcohol are mentioned in the preceding history of the particular bodies, and reference may be had to the metals for the solubility of the metallic salts; corrosive sublimate is very soluble.

(m.) It remains to be added, that *alcohol forms definite crystalline compounds*, as water does; they are called *alcohates*, as the other are

* Vol. i, p. 87.

† Ann. de Ch. et de Ph. Vol. xv, p. 395.

‡ A coil of fine platinum wire remains ignited in the vapor of alcohol. See the same fact mentioned under ether, (l.)

§ Am. Jour. Vol. xviii, p. 261.

|| The vapor will be condensed in the tube, and lime water will detect the carbonic acid in the bottle.

¶ Carbonate of potassa excepted.

** Wenzel's table, quoted by Henry; the specific gravity of the alcohol is not mentioned.

†† Muriate of potassa is slightly soluble, and even, according to Mr. Chenevix, muriate of soda.

hydrates. *Anhydrous alcohol is heated with the anhydrous bases,* and, on cooling, the alcohates crystallize, more or less distinctly; they are deliquescent, and of course soluble both in water and in alcohol.* Taking 23 for the equivalent of alcohol, the salts named below, unite respectively, with the number of equivalents of alcohol denoted by the numbers following their names. The muriates (chlorides) of lime (3.5), manganese (3.5), and zinc (.5), and the nitrates of lime (2.5), magnesia (9.), all these have been proved to form alcohates. The crystals are soft and easily suffer the alcoholic fusion, analogous to the aqueous, of common crystals; in some of the alcohates, the spirit is not expelled by a heat of 4 or 500° F.†

(n.) *Alcohol, by uniting with the water, precipitates some salts from their aqueous solutions; the sulphates and most of the nitrates are conspicuous examples, especially in concentrated solutions; repose and heat are in some cases necessary to the effect; those salts that are very soluble in alcohol are not precipitated by it.*

(o.) *Alcohol is a powerful antiseptic; hence its utility in museums, and anatomical collections, and in preserving organic matter generally from putrefaction.*

(p.) *Decomposed, by being passed, in vapor, through an ignited tube; products, carbonic oxide and carburetted hydrogen gas; charcoal lines the tube; 3 oz. of alcohol produce 10 cubic feet of gas.*

IV. COMPOSITION.

(a.) *Alcohol, consists of carbon, oxygen‡ and hydrogen. As potassium and sodium, when placed in alcohol, become alkalies and evolve hydrogen gas, it is obvious that the elements of water exist in this fluid.*

(b.) Proportions.

Carbon, 12=2 equiv. }	}=23 its equiv.; per cent. §	{	52.17
Oxygen, 8=1			34.79
Hydrogen, 3=3			13.04

In strictness, nothing more is necessary to be stated, to elucidate the composition of alcohol, but it not unfrequently results, from the beautiful doctrine of definite proportions, that principles may be assorted and supposed to be combined, in various ways, so as to present different proximate arrangements, with the same general result.

* The presence of a very little water will prevent the crystallization.

† Graham, in Eng. Quart. Jour. N. S. Dec. 1828.

‡ See Vol. I, p. 249, (f.), and p. 254, (j.)

§ Sausure, Nicholson's Journal, xxi, or Ann. de Ch. lxxxix; his alcohol had, at 62° F. the sp. gr. 0.8302; the numbers obtained by analysis were 51.98, 34.32 and 13.70, which are as near as could be expected to those corresponding with the equivalents. Dr. Ure gives carbon 8 equiv. + oxygen 2 + hydrogen 6; per cent. carbon 46.15, hydrogen 12.52, oxygen 40.03.—Dict. p. 125, 3d English ed.

(c.) Thus the 2 equiv. of carbon, 1 of oxygen and 3 of hydrogen, in alcohol, may be arranged as follows; 2 equiv. of carbon + 2 of hydrogen = 1 of olefiant gas = 14, its equiv.,* and 1 of oxygen + 1 of hydrogen = 1 of water, $9 + 14 = 23$ equiv. of alcohol; and alcohol may therefore be composed of olefiant gas and water.

The proportions, by volume, are obtained thus; the equiv. of olefiant gas $14 \div 0.972$ (sp. gr. of olefiant gas) = the volume of olefiant gas; water $9 \div 0.625$ † (sp. gr. of aqueous vapor) = the volume of watery vapor; and if, instead of .14 and 9, we take 100 and 64.29, (numbers in the same proportion,) the quotients will be, for the gas 102.75; for the vapor 102.86; we may therefore conclude that the volumes are equal; if the two volumes are condensed into one, then the specific gravity of the vapor will be $0.972 + 0.625 = 1.597$, and this approximates so nearly to the result of experiment by Gay-Lussac, i. e. 1.613 for the sp. gr. of the vapor of alcohol, that it leaves no room for reasonable doubt‡ that it has the constitution indicated by that eminent chemist.

V. USES—DANGERS.

(a.) *The utility of alcohol is manifest from its numerous applications in the arts, in science and in medicine*; as a medicine, it should however be administered only in the smallest efficient doses, and stopped as soon as the object is attained.

(b.) As proof spirit, in considerable doses,§ kills, and absolute alcohol kills, in small, *it is improper as a continued diluent or refreshing drink*. When used in this manner, and in increased quantity, it subverts the physical powers, and induces ultimate ruin of all the faculties.

(c.) *As it exists in the natural fermented fluids, in small proportion, combined or blended with much water, with sugar, mucilage, acids, tannin, coloring matter, salts, and often with carbonic acid, it is greatly mitigated in power and modified in character; such fluids, in moderate quantity, and containing no more alcohol than is generated in them by their own fermentation,|| are grateful and often useful refreshments, but, to persons in health, especially in youth, they*

* Vol. I, p. 404, (6.)

† Quoted in Vol. I, p. 88, as 0.628; the variation will not appreciably influence the result.

‡ As there is still some disagreement as to the exact composition of sugar, I have not introduced Gay-Lussac's comparison between it and the alcohol and carbonic acid, resulting from vinification; there can however be no doubt that the sugar or the farina which disappears is adequate to the formation of the alcohol and of the carbonic acid. See Ann. de Chim. Vol. xciv, p. 311. See also H. T. and M.

§ Mr. Brodie, Phil. Trans. for 1811, p. 178.

|| The alcoholized wines may be useful in certain states of health and at certain periods of life; in general, however, their use should be only occasional and temporary.

are not necessary; their excessive and continued use, induces, at a later period, the same consequences as those produced by alcohol.

ETHER.

Remarks.—Our elementary ideas on this subject are derived from sulphuric ether, which is familiarly known.

The ethers are volatile, odorous and inflammable fluids, produced between alcohol and various acids; their number is now considerable, and they are divided, in consequence of modern discoveries, into three classes, as follows:

CLASS I.—ETHERS COMPOSED OF OXYGEN, CARBON AND HYDROGEN; they do not contain any portion of the acid which forms them, and the elements are so combined as to form water and olefiant gas.

1. SULPHURIC ETHER.—This is by far the most important.

I. HISTORY.—Discovered in the sixteenth century; it is mentioned in the Pharmacopœia of Valerius Cordus, published at Nuremberg, in 1540; but its properties have been particularly studied only during the last century.*

II. PREPARATION.

(a.) *Rectified alcohol and strong sulphuric acid, equal weights;* place the alcohol in a large tubulated glass retort, held over a bowl;† add the acid by degrees, with intermediate and careful agitation, pouring it through the tubulure or through a retort funnel; much heat is evolved; the fluid turns brown and the ethereal odor is instantly perceived; a tubulated or quilled receiver is applied and kept cold, and the ether is distilled by a sand heat or by a bath of hot brine.‡ At first, alcohol rises, but the ether immediately follows; the gentle ebullition, which begins at 208°, must be continued, until white vapors appear in the retort.§ If half as much alcohol, as at first, is now added to the materials, more ether will be obtained; by repeated additions, the same acid will produce more than its own weight of ether.||

(b.) *It will contain sulphurous acid, which is removed by standing a few hours on potassa,¶ or by agitation with a strong solution of that alkali in water; the ether floats and is then decanted and again*

* Thénard, 5th ed. Vol. iv, p. 146.

† As a security against fracture from the heat, which, however, in many trials I have never met with.

‡ A common retort and receiver will answer, but they must be loosely joined.

§ Sulphurous acid gas, carbonic acid gas, and ultimately olefiant gas, are evolved, and a bulky deposit of charcoal remains, as stated Vol. I, p. 403.

|| It is said two or three times as much, but the acid becomes eventually too much weakened to attract the water any farther.

¶ Or on its carbonate, or on muriate of lime.—Murray.

distilled,* till one half has come over; it will now have the sp. gr. of about .75, instead of .78 or .79 as at first, and will be, in quantity, perhaps one third of the weight of the alcohol, of which fluid it still contains a portion; it may be removed by washing with water, as follows.

(c.) *Place the ether in a bottle, with about twice as much cold water, leaving a space of air above*; insert the stopper, or cover the mouth with the hand, and agitate the fluids together; on standing, the ether will rise to the top, in innumerable minute globules, and may be drawn off by a syphon, or recovered by a filtering funnel, or by a common glass funnel, stopped with the finger, the water being allowed to escape and the ether being retained; the washing may be repeated two or three times, and the ether will now be very pure.†

(d.) *The oil of wine*, as it has been called, is *produced during the distillation of ether*; it will soon be mentioned again.

III. PROPERTIES.

(a.) *Limpid, colorless; odor fragrant and, to most persons, grateful; taste, warm and stimulating.*

(b.) *Refractive power, high*; sp. gr. usually .700 to .713, water being 1,000, or according to Lovitz .632; *that of the shops is about .74° or .75°*, and even heavier, as it usually contains alcohol.‡

(c.) *Very volatile*;§ evaporates rapidly in the open air; *boils at 96° or 98° F.*, when it is at the density of .720 and in a vacuum at 40°. *When it is of the sp. gr. of .713, it boils at 93 $\frac{2}{3}$ ° F.*, and in vacuo at — 20°, producing so much cold as readily to freeze water.|| Water is also frozen by a small stream of ether, trickling upon the tube containing it.||

* From black oxide of manganese, which converts the sulphurous acid into sulphuric acid and forms sulphate of manganese.—*Id.*

† The vapor rising from the water of these washings is inflammable; according to my experience, there is no advantage in repeating the washings more than twice, or at the utmost thrice, the alcohol being then probably all removed, and if we continue the washings we waste the ether, which is in a small degree (about one tenth) soluble in water, and water is also slightly soluble in ether, so that the upper stratum is this solution and the lower etherized water.—*Thénard.*

‡ *Mr. Dalton's table.*

Ether.	Alcohol.	Sp. gr.	Ether.	Alcohol.	Sp. gr.
100	+	0 =	40	+	60 =
90	10	0.720	30	70	0.792
80	20	0.732	20	80	0.804
70	30	0.744	10	90	0.816
60	40	0.756	0	100	0.828
50	50	0.768			0.830
		0.780			

Constructed from experiments on mixtures of ether of .720 and alcohol of .830.—*H.* I give this table as I find it, although the sp. gr. of the ether is greater than that of absolute ether as stated in the text.

§ A mixture of sulphuric and muriatic ether is instantly vaporized and produces a cold below 0.

|| Vol. I, p. 106 and 111.

(d.) Two ounce measures of ether, when vaporized, will fill a cubic foot; its density is 2.58, air being 1.

Ether is highly convenient for illustrating the theory of vapor; the principal facts and conclusions have been already stated, Vol. I, pp. 87, 96, &c. and need not therefore be repeated; it will be remembered, that the force of its vapor, like that of other fluids, is, at the boiling point, equal to sustaining 30 inches of mercury.

(e.) *Rectified ether flows through a capillary tube nearly four times as fast as water,* and more than eight times as fast as alcohol, but it does not rise so high by capillary attraction, as either of them.*

(f.) It freezes at -46° or -47° F.

(g.) *Its solvent powers are less extensive than those of alcohol;* it dissolves essential oils and resins, a little† sulphur and phosphorus, and some of the vegetable alkalies. *Phosphorized ether‡ is a medical preparation;* it is necessary only to put some phosphorus into a vial of good ether, 8 grs. to the ounce, stopping it from the air, and it will soon be dissolved; by evaporation it deposits crystals.

(h.) *By careless keeping in the light, ether becomes sour,* acetic acid being generated by its decomposition,§ and a peculiar oil is developed, which ether probably contains, since, by evaporation on a plate of glass, it always leaves a stain.

(i.) *It is highly inflammable;*|| if a drop or two of it be agitated in a large air jar covered by a glass plate, the whole volume of air will take fire on the approach of a lighted candle.¶ It enlarges the volume of gases. *Oxygen gas, mingled with ethereal vapor, is doubled in volume at 60° or 70° , and is rendered violently explosive* as it would be by hydrogen gas. It is easily made to burn in a jet, from an air jar filled with hot water, or from a bladder.**

(j.) *A coil of fine platinum wire, placed above either alcohol or ether, and ignited by kindling their vapor into flame, will remain ignited†† after the flame is extinguished: this is well exhibited in a*

* Ann. de Chim. et de Phys. Vol. vi, p. 239.

† One thirteenth in the light, one seventeenth in the dark.

‡ In the opinion of Dr. Tully, the phosphorized oil is better, as the phosphorus in the phosphorized ether precipitates by contact of water or of the saliva.

§ Ann. de Chim. et de Phys. Vol. ii, p. 213.

|| A lump of white sugar, filled with ether and thrown into a vessel of hot water, creates a boiling fountain, and a flaming one, if a burning candle is applied.

¶ Much caution is requisite to avoid accidents with both alcohol and ether, and especially with the latter, more particularly, when it has been exposed, by pouring or otherwise; it may thus render the entire air of a room inflammable; I have seen the flame dart, several feet, from a candle to the mouth of a vessel containing ether, which of course, instantly boils and produces an uncontrollable combustion, dangerous alike to the persons and premises.

** See Vol. i, p. 96, 5, a, b.

†† Vapor of acetic acid, modified by holding in solution a compound of carbon and hydrogen, is exhaled in rather irritating fumes; it was, for a while, supposed to be a new acid.—Eng. Quart. Jour. Vol. VIII, p. 77, and Vol. VI.

wine glass, a glass plate being used to extinguish the flame, and being immediately after removed.*

(k.) *Chlorine causes the spontaneous combustion or explosion of ether*; a rag imbued with ether, may be introduced into chlorine gas; or, into a bottle containing 3 or 4 pints of the latter, a drain of ether† may be cautiously poured, by a glass fixed to a pole; muriatic acid, carbonic acid gas, and precipitated carbon, are the results.

IV. COMPOSITION.

(a.) *The combustion of ether produces carbonic acid and water*; its decomposition, by passing it, in vapor, through an ignited tube, affords carburetted hydrogen, oxide of carbon, a little carbonic acid, oil and charcoal, and, *by explosion of its vapor with oxygen, its constitution is more exactly determined.*

(b.) By the researches of Saussure, on ether of sp. gr. .715, and by those of Dumas and Boullay, on ether of .713, corrected by calculation, it appears to have the following composition:—

	Saussure,	Dumas and Boullay,	Calculation.†
Carbon,	67.98,	65.05,	64.96,
Oxygen,	17.62,	21.24,	21.57,
Hydrogen,	14.40,	13.85,	13.47,
	100.	100.14	100.

(c.) *It is supposed, that ether differs from alcohol in having 2 equivalents of olefiant gas, and 1 equivalent of water, and that, therefore, its own equivalent will be $28 + 9 = 37$.*

If alcohol consists of one equivalent of each, then in ether, there will be one equivalent of olefiant gas and half an equivalent of water; but to avoid the fraction, we suppose alcohol to have 2 equivalents of each, and then ether, whether in weight or volume, will be constituted as above.

The sp. gr. of ethereal vapor, found by experiment, is 2.581, and if the two volumes of olefiant gas, sp. gr. $.972 \times 2 = 1.944 + .625$, the

* A night lamp has been constructed upon this principle, first discovered by Sir H. Davy. See Am. Jour., Vol. iv, p. 828, and this work, Vol. i, p. 128. The same principle is applied in the safety lamp.

† Nicholson's Jour. 4to, Vol. v, p. 205.

‡ Dr. Ure finds the composition to be

	Experiment.	Calculation.
Carbon, - - -	59.60	60.
Hydrogen, - - -	13.30	13.33
Oxygen, - - -	27.10	26.26
	100.	100.

and he infers 3 volumes of olefiant gas and 2 of water, making the sp. gr. of the vapor 4.1666.
—Dict. 2d Eng. ed. p. 429.

sp. gr. of aqueous vapor, are condensed, the three volumes into one, it will give 2.569 for the sp. gr. ; a coincidence so near, as to leave no doubt that *the conclusion is correct.**

Etherification, therefore, consists in the abstraction from alcohol, of one equivalent of water ; this is the sole agency of the sulphuric acid, and of several other acids, such as the phosphoric, arsenic and fluoboric, which produce the same result.

We now understand, why so large a portion of sulphuric acid is necessary to produce olefiant gas ;† it takes away all the water and liberates this gas, which is the other constituent ; the evolution of carbonic acid, sulphurous acid, and carbon, are mere incidents, arising from the too energetic action of the hot acid on the alcohol.

V. USES.

(a.) *In relation to the animal economy, ether is a diffusible stimulus of the greatest activity.*

(b.) *When inhaled as a vapor, in cases of difficult breathing, spasms, &c. it often gives instantaneous relief.* It is breathed from sugar, from a vial, or from a tunnel, placed over a tea cup, from which the ether is vaporized by a warm water bath.‡

(c.) *When placed in the hand and pressed upon the face, head, or any other part, it produces a tingling heat, and on removing the hand, sudden cold follows, and pain is sometimes thus relieved.*

(d.) *In chemistry, it is an active solvent for caoutchouc, &c. as already stated.*

OIL OF WINE.—SULPHO-VINIC ACID.

1. Process.

(a.) *The oil of wine is a product in the distillation of alcohol and sulphuric acid, after the ether has ceased to rise ; the receiver being changed and heat continued, sulphurous acid is freely evolved, and a small portion of yellow oil is condensed, long known by the name of sweet oil of wine ; the process ends, as above, with the evolution of olefiant gas, charcoal, &c.§*

(b.) *Equal measures of acid and alcohol yield a larger product of the oil ; after standing half an hour, the free sulphuric acid is precipitated by carbonate of lead ; the sulpho-vinic acid remains in solution, and with the bases forms sulpho-vinates.*

* Ann. de Chim. Vol. xcv, p. 311, Id. Vol. lxxxix, p. 294.

† 2 or 3 measures to 1. Vol. i, p. 402, (3, a.)

‡ It is sometimes breathed for the sake of the sensations which it produces ; this is in every view improper, and may prove dangerous or even fatal.

§ The sulphuric acid may be filtered through powdered glass or sand, and will serve for another process.

2. *Properties of the sweet oil of wine.*—Fragrant, pungent and bitterish; sp. gr. 1.060; it combines with alcohol but not with ether; does not affect the test colors for acids.

3. *Composition.*—It is not necessary to recite former discarded opinions; the view of the subject given by Mr. Faraday* and Mr. Hennel,† and now admitted, is as follows.

(a.) *The sweet oil of wine has, for its basis, a compound of carbon and hydrogen, (hydro-carbon, or carburet of hydrogen,) in the proportions forming olefiant gas; the other constituent is sulphuric acid, and the proportions are 2 of the acid, 8 of carbon, and 8 of hydrogen.*

(b.) *These principles are combined, in such a manner, that the whole of the acid, with half of the carbon and hydrogen, forms a new and peculiar acid, to which the name of sulpho-vinic acid is given,‡ and the remainder of the carbon and hydrogen is combined, in the manner of a base, with the peculiar acid; this fluid, the oil of wine, although it contains sulphuric acid, exhibits no acid character, and gives no precipitate with solution of baryta, but, on being then boiled to dryness, after the application of baryta, sulphate of baryta is obtained in such proportion as to imply 37 or 38 per cent. of acid in the oil.*

(c.) *The oil of wine, when heated, gives up half the carbon and hydrogen, and is then sulpho-vinic acid, with 2 equiv. of sulphuric acid, 4 of carbon, and 4 of hydrogen, and the sulpho-vinic acid saturates bases, in proportion to one half of its sulphuric acid; potassa, added to oil of wine, gives, by evaporation, a sulpho-vinate, containing the above proportions of the acid, with 1 of potassa.*

(d.) *That part of the carbon and hydrogen, not entering as an element into the constitution of the sulpho-vinic acid, crystallizes spontaneously, 1 equiv. of each element, being in the same proportions as in olefiant gas; and by agitation with alkaline or pure water, it appears in the form of an oil, odorous, combustible, soluble in ether, and containing 85.61 carbon, + 13.11 hydrogen.§*

The existence of sulpho-vinic acid and of the salts, called sulpho-vinates, appears to be sufficiently established.

2. PHOSPHORIC ETHER.

Deliquesced, or partially inspissated phosphoric acid is distilled with alcohol, some of which rises unchanged, and then follows the

* Ann. de Ch. et de Ph. Vol. xxxiv, p. 167.

† Phil. Trans. 1826, p. 247. Eng. Jour. of Science, Vol. xxi, p. 331.

‡ First mentioned by Dabit, pharmacist at Nantes, in 1800, Ann. de Chim. et de Phys. xiii.

§ For other views and facts on a subject which is not important enough to be here treated more in detail, see the memoir of M. Hennel, above cited; also Ann. de Chim. et de Phys. Vol. xiii, and Id. Vol. xxxiv, xxxv, xxxvi, xxxvii.

ether, which differs, in no respect, from that which has been described. The same is true of the arsenical ether.

As these ethers are of no particular use, I refer for more details to Thénard's Chem. 5th Ed. Vol. iv, p. 158, to the Jour. of Phar. Vol. i, and to Ann. de Chim. et de Phys. Vol. xiii, p. 294.

CLASS II.—ETHERS FORMED WITH ACIDS, containing hydrogen, in the place of oxygen, (hydracids); these ethers are composed of the acid and olefant gas.

1. MURIATIC ETHER.

I. PREPARATION.

(a.) *By saturating alcohol with muriatic acid gas, and distilling the impregnated fluid.*

(b.) *Better, by mingling, in equal measures, alcohol with strong muriatic acid, and distilling the mixture in a glass retort, connected with a cold tubulated or quilled receiver, or with a Woulfe's apparatus, the second bottle of which should be surrounded by ice.**

II. PROPERTIES.

(a.) *Volatilized at 70°, and begins to form vapor at 51°; may be permanently vaporized, in inverted bottles, filled with water maintained at 80°; sp. gr. of its vapor 2.219, air being 1.; that of the fluid, at 40°, is .870; its vapor is condensed at 50°; smells like sulphuric ether; it boils in the palm of the hand, producing much cold.*

(b.) *Dissolves in one volume of water; taste of the solution, saccharine and aromatic, like peppermint; dissolves readily in alcohol, and water separates it again; does not congeal at -22° F.*

(c.) *Does not precipitate nitrate of silver, or proto-nitrate of mercury, or redden vegetable blues.*

(d.) *Still, it is proved to contain muriatic acid, for during its combustion, muriatic gas is liberated, with carbonic acid and aqueous vapor.*

(e.) *Composition*—ascertained by passing it through a porcelain tube, scarcely ignited; *products of the igneous decomposition, equal volumes of muriatic acid gas and olefant, which appear to be united, without condensation, as the sum of their sp. gr. 1.278 + .972 = 2.250, which is very near that of the vapor of this ether.†*

(f.) *Fired, with oxygen 3 and ether 1, it detonates violently, and breaks a common glass eudiometer.*

* From 10 oz. of the acid and an equal measure of alcohol, 1.2 oz. of ether may be obtained. It is said, that muriatic ether can be procured by distilling alcohol with fuming chloride (muriate) of tin.—*Murray.*

† Robiquet and Collin, Ann. de Chim. et de Phys. Vol. i, p. 248.

2. HYDRIODIC ETHER.

1. *Preparation*—by Gay-Lussac, its discoverer.*

Distil, in a water bath, equal† measures of the colorless acid, sp. gr. 1.7, and alcohol, and receive the product in a bottle containing water; it collects in globules and looks milky, but soon forms a colorless fluid.

2. *Properties*—very similar to those of other ethers; its chief peculiarities are, a sp. gr. of 1.92 at 72° F.; becomes rose colored by keeping, and again colorless by contact of mercury and potassa, which remove the liberated iodine; boils at 156° F.; in the cold, its vapor does not kindle by the flame of a taper; on burning coals, exhales purple vapors of iodine; potassium remains‡ in it unaltered. The fluoric,§ fluoboric,|| chromo-sulphuric,¶ and other ethers are at present too obscure and unimportant to detain us.

CLASS III.—ETHERS** COMPOSED OF OXY-ACIDS AND ALCOHOL.

1. NITRIC ETHER.

Remark.—The action of nitric acid upon alcohol is violent, especially if it is strong; †† it demands particular care, to avoid dangerous accidents. ††

I. PROCESS.§§

(a.) *Aqua fortis and alcohol of commerce*, not over half a pint of each, mingled in a retort of more than double the capacity, and con-

* Ann. de Chim. Vol. xci, p. 89.

† Ure: 2 alcohol and 1 colored acid, Thénard, Vol. iv, p. 164. Serrullas distills (into a receiver containing water) a phosphuret of iodine, (8 phosphorus + 1 iodine,) with some iodine in a free state, and 2½ parts of alcohol, (Id.)

‡ The usual statement that potassium will keep only in naphtha, needs therefore to be qualified; it is now known to keep in oil of copaiba.

§ Nicholson's Jour. Vol. viii, p. 143.

|| Recher. Phys. Chim. Vol. ii, p. 89; Ann. de Chim. et de Phys. Vol. xvi, p. 72.

¶ Ann. de Chim. et de Phys. Vol. xvi, p. 102.

** It is rather doubtful whether this class is correctly described in this title.

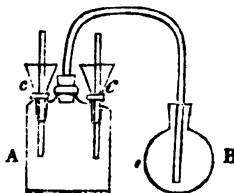
†† A small flask may be charged with an ounce or two of nitric acid and alcohol, and when the action comes on, with or without heat applied, the vapor, if fired, blazes to the height of several feet.

‡‡ If strong nitrous acid is poured into a glass from which high alcohol has just been emptied, and with which it is still wet, it will fly out with explosive violence, and may dash the acid in the face and eyes.

§§ Our books often neglect to mention the strength of the materials; strong nitric or nitrous acid and high alcohol might occasion a dangerous explosion, and should never be heated as described in the text, unless in very small quantities. Dr. Hare has an ingenious apparatus which I have used with safety, with the strongest acid and alcohol; see Dr. Hare's Compendium.

Dr. Torrey's apparatus for Nitric Ether.

A, Woulfe's bottle; B, receiver; c c, glass funnels ground to the necks, and glass rods ground to the funnels, the acid being in one funnel, and the alcohol in the other.



nected with a Woulfe's apparatus; the first bottle, as usual, is for waste, and the others being filled with saturated brine, are contained in a box full of ice, or better, of snow and salt; *a gentle heat of a few coals is applied*, but is withdrawn at the first appearance of ebullition, and the latter, if too violent, may be checked by a moist sponge or rag applied to the retort; the process is through, when the boiling ceases; the ether will be condensed in the first brine bottle, and will be in quantity about $\frac{1}{3}$ of the alcohol; *various gases are disengaged*.

(b.) *Dumas and Boullay** used equal weights of nitric acid and alcohol, sp. gr. .820; about 200 grammes of each† in a retort of 3 pints; it was not necessary to cool the retort, the fire being promptly withdrawn after the action began; the process was quiet, and from 45 to 50 grammes of purified ether were obtained; this is substantially the process of Thénard, which is usually quoted.

II. PROPERTIES.

(a.) *Color yellowish; odor fragrant*, but penetrating and producing giddiness; taste acrid and burning; usually contains acid and reddens litmus; it is rendered neutral by distillation from quick lime, but soon becomes acid again, evolving nitrous and acetic acids, and a similar change is induced by mixing it with water or distilling it at a high heat; sp. gr. .886 at 40°, *heavier than alcohol, but lighter than water*; soluble in 48 parts of the latter.

(b.) *Very combustible and volatile*; boils at 70° F. and sustains 30 inches of mercury; sp. gr. of its vapor 2.628, the warmth of the hand produces bubbles in a vial of this ether.

(c.) *It quintuples the volume of oxygen gas.*

(d.) *Composition*—according to Thénard, the nitric acid is, by a part of the alcohol, turned into nitrous, which combines with the alcohol;‡ *anhydrous nitrous acid and alcohol produce nitric ether*. Dumas and Boullay analyzed it by oxide of copper, and found carbon 32.69, + nitrogen 19, + hydrogen 6.85, + oxygen 41.46 = 100, or 4 equiv. of carbon, 5 of hydrogen, 1 of nitrogen, and 4 oxygen, which may be supposed to form 2 equiv. of olefiant gas, 1 of water, and 1 of hypo-nitrous acid.

(e.) *Nitric ether is decomposed by being passed through an ignited tube*, yielding water, ammonia, oil, carbonic acid, prussic acid, deut-oxide of nitrogen, nitrogen, carburetted hydrogen, &c. besides loss.

Remark.—The sweet spirit of nitre, of the shops, is alcohol containing some nitric ether; it is produced by mingling 2 pints of alcohol with 3 oz. of nitric acid and distilling. The pure nitric ether is not

* Ann. de Chim. et de Phys. Vol. xxxvii, p. 26.

† The gramme 15.5 grains \times 200 = 2100 grains of each, or 4200 of both.

‡ Upon this supposition, it is arranged by Thénard, whom I have followed.

used in medicine, and is known only to the chemist. It was discovered by Navier, a physician at Chalons, France.

2. ACETIC ETHER.

Remark.—This is the only one of the vegetable acids which, by a direct action upon alcohol, forms an ether.

I. PROCESS.

(a.) *The best acetic acid*, from acetate of copper, *is distilled*, 10 or 12 times, with an equal weight of alcohol; it is rectified by potassa.

(b.) Strong acetic acid 63 parts, rectified alcohol 100, sulphuric acid 17; distil about 120 parts, from a tubulated retort into a large cold receiver; purify it by agitation with potassa in a vial, and with repose, the ether will float; the sulphuric acid favors the action, but does not form part of the ether.

(c.) *Acetate of potassa** 3, + 3 alcohol, + 2 sulphuric acid, *distil to dryness*, and then redistil with $\frac{1}{2}$ sulphuric acid.

II. PROPERTIES.

(a.) *Volatile, evaporates in the air; boils at 123° or 160°;†* density of the vapor 3.067; *acetic acid is evolved during its combustion*, although not discoverable in the ether; it fires by a lighted taper.

(b.) *Colorless; odor grateful*, like that of vinegar and sulphuric ether mixed; sp. gr. .816; *soluble in 8 parts of water*; potassa destroys its odor and taste, and when the fluid, which is not acid, is distilled, weak alcohol is obtained, and acetate of potassa remains.

(c.) Like other ethers, *soluble in alcohol and separable by water*; in medicine, it is stimulating and diuretic.

(d.) *Composition*—1 equiv. of acetic acid, + 1 of ether, which, in properties, is exactly like the sulphuric ether.‡

The ethers, supposed to be formed with other vegetable acids, the benzoic, malic, oxalic, citric and tartaric, present nothing particularly important; they are all produced, by the agency of a mineral acid, and it is possible that they are not distinct ethers; Dumas and Boullay find them composed of 1 equiv. of the peculiar acid, + 1 of sulphuric ether, or, what amounts to the same thing, of 1 equiv. of water, + 2 of olefiant gas.§

Remark.—CHLORIC ETHER was described, p. 19 of this volume. Strictly, it does not belong to either of the above classes.

* Other acetates may be employed with other proportions of sulphuric acid.

† Dumas and Boullay.

‡ Ann. de Chim. Vol. lxi, p. 45.

§ For other facts and views, see their memoir, Ann. de Chim. et de Phys. Vol. xxxvii; also Thénard's Chem. 5th Ed. Vol. iv, p. 174, &c.; Mem. d'Arcueil, Vol. ii, p. 5, and Phil. Mag. Vol. xxxvii, p. 216.

III. ACETOUS FERMENTATION.

Remarks.—The acetous fermentation is that which produces vinegar, or the acetic acid; in the natural order of changes which take place, spontaneously, in saccharine, mucilaginous and farinaceous fluids, it frequently follows the vinous fermentation, and therefore it is introduced in this place. The acetic acid results from two very different conditions.

1. It follows the vinous fermentation, and spirit is changed to vinegar.

2. It sometimes takes place, without the previous production of alcohol, and frequently in substances not saccharine.

1. The acetous fermentation follows the vinous.

The indispensable requisites are

1. A fluid containing wine, or alcohol and water.
2. A temperature of from 60° to 80° ; the fermentation is languid at 50° , and null at 32° ; above 80° it is very active.
3. A ferment, either contained in the liquor, or added, or both.
4. A free contact of oxygen gas or of the air; for, the acidity of wine is usually produced by oxygen, and the other circumstances are only auxiliary.

Malt liquors, weak wine and cider, are the principal sources of the vinegar of fermentation; the vinegar of destructive distillation (pyroligneous acid) will be mentioned by itself. These fluids, after they have undergone the vinous fermentation, often pass, spontaneously, to the acetous state; they always do so in a proper temperature, if a ferment is added. Even alcohol, if largely diluted, suffers the same change, when mixed with yeast. The fluids grow warm and turbid; a ropy, filamentous matter is deposited, oxygen gas is absorbed and carbonic acid gas is disengaged; in the acetous fermentation, the access of the air is therefore, in most cases, indispensable; in the vinous, on the contrary, at least after the process has commenced, the air may be entirely excluded. *In the acetous fermentation, however, unless at a high temperature, there is not so much turbulence of movement as in the vinous;* the oxygen gas is quietly absorbed and the carbonic acid gas* quietly disengaged, and Saussure† ascertained that these two operations are equivalent, all the oxygen absorbed being contained in the carbonic acid evolved. *After the fermentation is finished, all movement ceases;* the fluid becomes clear and is found to be vinegar.

Even in rich saccharine fluids, the changes are prevented by cold, and by exclusion of the air; and they are always induced by the opposite. It appears to me proper to include under this head the aceti-

* In much less quantity, however, than in the vinous fermentation.

† Recherches sur la Veget. p. 9.

fication of vinous fluids, although the oxygen of the air is not admitted. It often happens that weak bottled wine, cider or beer, turns sour; if the bottles are imperfectly corked, the effect may be attributed to the oxygen of the air, and then the liquor will not be sparkling, but merely sour and not spiritous. We often find, however, that bottled cider, although sparkling with carbonic acid gas, is sour and not vinous. In this case, the air cannot have had access by the cork, otherwise the carbonic acid would not have been retained; the acetification has therefore arisen from an internal change; some of the oxygen of the sugar or spirit, or both, having combined with a part of the carbon to form carbonic acid, and probably another portion with hydrogen to form water; thus the sugar and spirit are both subverted, and vinegar comes in their place. The ferment which favors these changes often exists in the fluid.

2. *Acetification without alcoholization.*

Most vegetable and some animal substances become sour, in certain stages of decay, and an acid is formed, which is generally supposed to be the acetic. Thus, mucilage and many vegetable infusions become sour by keeping in close bottles; if sugar be added to starch water, that has stood on the gluten of wheat, it generates vinegar, without the previous formation of alcohol. It is said that all, or nearly all substances, that are capable of that change, may be made to afford vinegar, without having first perfectly undergone the vinous fermentation.†*

The nature of the change, in acetification, is not perfectly ascertained.—We can say, however, that in vinous fluids, and especially in those that are saccharine, oxygen, from the air or from their own substance, aids in removing carbon, and in thus subverting both the spiritous and saccharine constitution. Where the acetification is not preceded by the formation of spirit, and especially where the air is excluded, the change must be internal and must consist in a new, but unknown arrangement of the elements.

ACETIC ACID.—VINEGAR.

Remark.—It was formerly supposed that there are two acids, the acetic and the acetous, differing in the proportion of oxygen; but it has been fully ascertained, that the distinction is unfounded, and that they differ only in their state of dilution. Some writers, however, retain the term acetic for the strongest acid, such as exists in

* This is always the case with mucilage of gum arabic, kept in a close vessel the year round, unless counteracted by some antiseptic.

† Murray, El. 6th ed. Vol. ii, p. 564.

verdigris and in sugar of lead, and the term acetous for distilled vinegar and other weaker varieties.

VINEGAR.

This was probably known earlier than any other acid, and from it we have derived our elementary ideas of these bodies.*

The word vinegar means sour wine,—wine being the principal source of vinegar in wine countries.

I. PROCESSES.

1. *From wine.*—In France, at Orleans, they arrange rows of large casks, preferring those that have been used before, and giving them, in winter, by the aid of fire, a temperature of 64° to 68° F.; the cask is at first $\frac{1}{4}$ filled with good boiling vinegar: eight days after, they add $\frac{1}{4}$ as much clear wine, and so on, the same quantity at the same distance of time, till the casks are full, and in fifteen days more the vinegar is made. About half is then drawn off and the same additions of wine are made as before, and at the same intervals, varying both, as the fermentation is more or less rapid. The vinegar of red wine is passed several times through animal charcoal, and is thus made even whiter than that from white wine;† without losing their aroma, both are clarified by agitation with boiling milk, the coagulum from which is easily separated. In Paris, the wine is pressed through the wine lees contained in sacks, and then treated nearly as above; it is drawn off into tight casks containing birch wood chips.‡ Vine twigs and grape stalks aid the fermentation.

2. *From malt liquors.*—One hundred gallons of the wort made from six bushels of malt, are mixed at about 75° F. with four gallons of yeast, and after thirty six hours, the liquor is drawn off into casks, which, with their bungs open, are exposed to the sun, and in winter are warmed by a stove; in three months the vinegar is fit for the manufacture of acetate of lead.§ Sometimes, raisins or grape cuttings are added, to improve the flavor and to aid the fermentation.

3. *From cider.*—This is almost the only source of vinegar in the northern states of North America. In families, the vinegar barrel is, in summer, placed in the garret or on the sunny side of a building, and in winter, in a room where it does not freeze. The refuse cider already sour, or the daily remains of the family consumption, are added to some good vinegar, or to the mother of vinegar as it is called. This is a white or yellowish ropy coagulum, of a gelatinous or mucilaginous appearance, which is formed in the vinegar, and acts as a ferment

* Vol. i, p. 105.

† Thénard, Vol. iv, p. 344, 5th edition. Ann. de Ch. Vol. lxxix, p. 81.

‡ For varieties in the processes, see Boerhaave, Chaptal, Gray, Ure, Aikins, Encyc. Arts et Met., &c.

§ Boerhaave, quoted by Ure.

upon cider not yet thoroughly acetified. I do not know that it has been analyzed; it is probably an azotized or vegeto-animal substance, and appears to sustain much the same relation to cider that yeast does to beer or wine. In this country, the acetous fermentation of cider is often aided, by putting into it a piece of dough, or of lean animal muscle, or by adding molasses, (usually on a sheet of paper coiled,) or the sugar which falls spontaneously from molasses; mashed currants aid the effect. In a few weeks, the vinegar will be formed. In family language, if it is too sharp, (acid,) it eats up (dissolves,) the mother of vinegar, (the ferment,) and is thus injured.

4. *From sugar*.—10 lbs. are added to 8 gallons of water, with yeast and raisins or grape cuttings; for the sake of the flavor, and perhaps to aid the fermentation, 12 pints of bruised gooseberries or other fruits are added, and by a process similar to that for cider, a good vinegar is produced in the course of a summer.

5. *From wood—pyroligneous acid*. *—Hard woods, as oak, ash, beech and birch, are heated in iron cylinders, around which plays the flame of a furnace; iron tubes carry off the vapors of the acid, (which is formed by the reaction of the elements of the wood,) and they are condensed, along with tar, in a proper refrigeratory; an immense volume of inflammable gases is evolved, which, in France, are burned to aid in producing the heat; 800 lbs. of wood afford 35 gallons of the crude acid, weighing about 300 lbs. and the charcoal (which is of a fine quality,) weighs about $\frac{1}{2}$ as much as the wood.† The acid is distilled and leaves about $\frac{1}{3}$ of tar; it is now a brown transparent vinegar with a smell of smoke, and in this state or after another distillation, is used to preserve animal muscle and fat from putrefaction.‡

If the distilled acid is saturated with lime, and the dried acetate gently torrefied, to destroy the empyreumatic vegetable matter, which gives the taste and smell, a pure strong and colorless vinegar will, by distillation with sulphuric acid, be obtained, and the same may be extracted from acetate of soda. This acid is sometimes so strong as to be caustic; it is a perfect antiseptic, but the animal substances preserved in it, (the pure strong acid,) will be sour, and will not have the agreeable flavor of smoke, because the volatile oil in which it resides has been destroyed by the heat.‡

* See Parkes' Chemical Essays for an excellent account of this important manufacture; this acid is used by the calico printers, the manufacturers of white lead and sugar of lead, &c. and the tar is also a useful product.

† These facts are now too generally known to need much illustration; 1 quart of the pyroligneous acid, added to the common pickle for hams, at the time they are laid down, and in the same barrel, will give them the flavor of smoke as perfectly, as if they had gone through the usual process of smoking.

‡ I am informed that the pyroligneous acid has recently fallen into some discredit in this part of the country, on account of its having been made so pure, that it has

The vinegar of wood and *all vinegars, may be purified, by adding to them the animal charcoal,** made by calcining beef or mutton bones in a covered crucible; it is stirred, occasionally, with the vinegar, which, in a few days, loses its color but retains its acidity; and after filtration, has no unpleasant flavor; even acetic acid is deprived of empyreuma, by digestion on the charcoal, made in the Prussian blue manufactories.

II. PROPERTIES of vinegar.—They are familiar; it is *acid and fragrant; color yellow or brown*, but varying with the source; *reddens vegetable blues*; contains saccharine, mucilaginous and coloring matter, and sometimes small portions of alcohol;† also, nitric, malic and tartaric acids, according to the fluid from which it has been formed; animalcules are found in it, often in great numbers; they are chiefly removed by a fine filter of paper,‡ and the other matters by distillation, but distilled vinegar has a burnt taste; it is better to distil it from charcoal which has been made to imbibe it; water rises first and may be wasted, and the vinegar may be retained.

Vinegar is both purified and concentrated by freezing, but its quantity is much diminished. Sp. gr. of the best malt vinegar 1.0204.—(H.) If sulphuric acid§ has been used to adulterate it, there will be an insoluble precipitate with muriate of baryta. Good vinegar should not be affected by ammonia,|| or by sulphate of soda,¶ or by hydro-sulphurets.**

ACETIC ACID.

Remark.—The purified vinegar is a weak acetic acid, and the purified and concentrated pyroligneous acid is as strong an acetic acid as can well be obtained.

in some cases, failed to impart the desired flavor of smoke. I have used it for a series of years with perfect success.

* Common animal charcoal contains carbonate and phosphate of lime. The latter is decomposed and an acetate of lime is formed; a portion also of the phosphate is dissolved by the vinegar. These impurities are easily detected by evaporating some of the acid to dryness; the acetate of lime communicates an unpleasant flavor to the vinegar. I always remove the earthy matter from the animal charcoal, by digestion in muriatic acid, and then washing it with diluted alkali.—J. T.

† From French vinegar, an ounce of alcohol is obtained from four pints of vinegar.

‡ With a good magnifying glass, hardly one can be detected in the vinegar after filtration, and the animalcules that are caught on the paper can scarcely be distinguished from its fibres.

§ A little sulphuric acid is allowed in England.

|| Which detects copper by a blue color.

¶ This would indicate lead by a white precipitate.

** These would detect lead by a dark cloud.

I. PROCESS.

(a.) *Acetate of potassa** 2 parts, or *acetate of lead*† 3, and *strong sulphuric acid* 1, distil from a glass retort into a cold receiver; the acetic acid is purified from the sulphurous, by a redistillation from a little black oxide of manganese.

(b.) Bin-acetate of copper, (crystallized *verdigris*,) is distilled without addition, from a glass retort placed in a sand heat; the retort may be nearly full; the first portions that rise are watery, and may be rejected, and the stronger acid comes towards the last;‡ the fluid is green and must be redistilled to free it from copper;§ it will then have a sp. gr. of from 1.056 to 1.080.

II. PROPERTIES of acetic acid.

(a.) *Odor pungent and refreshing; resembles however, a little, that of sulphurous acid*;|| it is a strong acid, and after being applied a little while, blisters the skin; powerfully reddens vegetable blues.

(b.) *Very volatile*; vapor rises spontaneously, unchanged, and when the acid is heated, the vapor is inflammable, burning with a white light.

(c.) *The strongest acid is still a hydrate*, with 1 equivalent of acid and 1 of water; it then crystallizes at a low temperature, and retains its solid form up to 50°; when, of sp. gr. 1.063, it crystallizes at 55°, and does not melt till nearly 70°.¶

(d.) When obtained with strong sulphuric acid from very dry acetate of soda, and rectified, it contains 65 or 66 per cent. of real acetic acid, and by freezing, it will be concentrated even to 80 per cent.; the acid that crystallizes at 55°, appears, from saturating an alkali, to contain about 83 per cent. of real acid.**

(e.) By transmission through an ignited tube, it is but partially decomposed.

(f.) The specific gravity of compounds of this acid and water, increases until the proportions are 5 of water to 1 of acid; it then decreases so that its specific gravity is no decisive criterion of its strength.††

* It may be procured in the shops; acetate of soda answers the same purpose; for an economical method by using this salt, see Ann. Philos. N. S. Vol. ii, p. 23, and Hen. Vol. ii, p. 400.

† If any sulphuric acid has gone over, it will be detected by adding a solution of acetate of lead.

‡ Ann. de Chim. Vol. lxiii, p. 267.

§ The very last product of the distillation is a pyro-acetic ether, produced by a new arrangement of the elements; potassa or its carbonate will free it from the acetic acid, and when redistilled, it is limpid, pungent, inflammable, evaporates in the hand, and produces cold; lighter than alcohol, but is miscible with water, and like sulphuric ether, decomposes muriate of gold.

|| If drawn into the lungs, it does not produce a sensation like that from the fumes of burning brimstone.

¶ M. Despretz obtained the crystallized acid by heating together the equivalents of fused and dried acetate of lead and boiled sulphuric acid. Eng. Quar. Jour. No. 14, p. 423, N. S.

** Eng. Quar. Jour. Vol. vi, p. 26.

†† See the table of the specific gravity of different compounds of this acid and water; Thomson's First Principles, Vol. ii, p. 135.

(g.) *Its strength is estimated by its power of neutralizing alkalis*; 100 parts, by weight, of real acetic acid saturate 290 of crystallized, or 107.7 of anhydrous carbonate of soda.*—H.

(h.) *Composition*.—From a comparison of the analyses of Gay-Lussac and Thénard, and of Berzelius,† it has been concluded that this acid consists of 4 equiv. of carbon, = 24 + 3 of oxygen, = 24 + 2 of hydrogen, = 50 its equivalent; Dr. Prout however, finds 1 equiv. more of hydrogen, and that, contrary to the fact with other vegetable acids, its oxygen and hydrogen are in exact proportions to form water; according to him, its equivalent is 51, composed of carbon, 4 equiv. = 24, + oxygen, 3 = 24, + 3 hydrogen, = 51.

Remarks.—*Acetic acid is of great utility* in the arts, in domestic economy, and in medicine. Its fumes, when diffused in a sick room, although grateful and refreshing, have however, no antiseptic power. This acid, in the form of acetate of potassa, is found in many plants, as the *Sambucus nigra*, *Phoenix dactylifera*, *Galium verum* and *Rhus typhina*; it is contained in perspirable matter and in new milk; the stomach produces it in disease.

ACETATES.

Soluble; difficult to crystallize; decomposed by heat and by sulphuric acid.

I. ACETATE OF POTASSA.

Anciently, digestive salt of Sylvius.

1. *Process*.—Synthetically between the acid and the alkali or its carbonate, or by double exchange between the acetate of lime and sulphate of potassa.

2. PROPERTIES.

(a.) *A foliated mass* is obtained by desiccation or fusion; *this salt crystallizes by slow evaporation*, in minute prisms, containing 1 equiv. acid + 2 water; *deliquescent*; dissolves at 60° in about 1 part of water and in 2 of boiling alcohol.

(b.) *Probable constitution*.—Acid, 1 equiv. = 50 or 51 + potassa, 1 equiv. 48 = 98 or 99.

(c.) The salt, crystallized by the aid of sulphuric acid, in a vacuum, contains 2 equiv. of water to 1 of the acid and a bin-acetate, formed by Dr. Thomson, crystallized in the same manner, in large transparent plates, flat and deliquescent, and containing 6 equiv. of water.

* In the English excise, hydrate of lime is used to saturate vinegar, and the specific gravity of the acetate is the criterion of the strength of the vinegar; Eng. Quar. Jour. Vol. vi, p. 255.

† Ann. Philos. Vol. iv, p. 323.

‡ For pharmaceutical details see the pharmacopeias.

The acetate of potassa, is often formed by merely mingling vinegar, or better, pure acetic acid and pearlashes; it is a diuretic and cathartic of decided efficacy.

II. ACETATE OF SODA.

1. *Process*.—By combining the acid and alkali; or, acetate of lime, 1 part, is formed by pyroligneous acid and lime, and decomposed by double exchange with sulphate of soda, 2 parts, (crystallized;) to produce good crystals, the alkali should be in excess; they are easily obtained by evaporation.

2. Properties.

(a.) *Permanent in the air; soluble at 60° in 2 or 3 parts of water*; form, derived from a rhombic prism; suffer igneous fusion at 550° F. but retain the acid; decomposed at 600°.*

(b.) *Composition*; acid, 1 equiv. 50 or 51 + alkali 1 equiv. = 32 = 82 or 83; per cent 60.98 + 39.02; for the

(dry,)	61.689	acid,	36.95	crystals,	50
	38.311	soda,	22.94		32
		water,	40.11		54
	100.				

100. 136 equiv.

This salt is employed in medicine for the same purpose as the acetate of potassa; it is much used for affording acetic acid by the aid of the sulphuric.

III. ACETATE OF AMMONIA.†

1. *Process*.—Formed between the acid and carbonate of ammonia.

2. Properties.

(a.) *Difficult to crystallize*; in vacuo, and aided by sulphuric acid, it deposits oblique four sided prisms.

(b.) *Deliquescent*; volatile at 253°, and condenses again in crystals.

(c.) *Composition*.—1 equiv. of acid, = 50 or 51 + 1 of ammonia, = 17 + 7 of water, 63 = 130 or 131.—*Thomson*.

This is an ancient febrifuge medicine, introduced by Mindererus, and is still used; it is often formed extemporaneously.

IV. ACETATE OF LIME.

Its formation has been already mentioned.

Difficult to crystallize; by evaporation, forms silky crystals, containing 6 equiv. of water. Soluble in water and alcohol; not deliquescent; when dry, phosphorescent at 250° F.

Composition—acid, 1 equiv. = 50 or 51 + 1 of lime = 28 = 78 or 79.

* *Annals of Philosophy*, N. S. Vol. ii, p. 143.

† Its solution was formerly called *Spiritus Mindereri*.

Not used in medicine; made from pyroligneous acid and lime for the manufacture of vinegar, and, by double exchange with alum, used to form acetate of alumina for the dyers and calico printers.—H.

V. ACETATE OF BARYTA—OF STRONTIA.

Formed synthetically.—The acetate of baryta forms irregular six sided prisms,* with dihedral summits; soluble in about its weight of water at 60°, and in less than 20 of boiling water; slightly soluble in alcohol; composition—acid 1 equiv. 50 or 51 + 1 equiv. of earth, 78 = 128 or 129, + 1 equiv. of water 9 = 137 or 138.

As a test, very useful in the laboratory.—Acetate of strontia has a sweetish taste; dissolves in about 2 parts of cold water; composition probably 48.08 acid + 51.92 base.—H.

The acetate of alumina has been already mentioned; it is used only in dyeing, and being formed with alum and acetate of lead or lime it has generally an excess of alum.

There are acetates of the other earths, but they are little known. The important metallic acetates have been described under the metals.

For a notice of the pyro-acetic spirit, or ether obtained by M. Chenevix, by distilling several metallic acetates, see Ann. de Chim. lxi, Ann. of Phil. viii, 69, and Henry, 11th ed. Vol. ii, p. 408.

Conclusion of the history of vegetable bodies.

When the chemist has ascertained the elements and proximate principles of plants, and the proportions in which they are combined, he has done his duty, and the historian of the science has performed his, when he has perspicuously arranged and recited the facts. It is however desirable to know what happens in the vegetation and decomposition of these bodies; this is a department of chemico-vegetable physiology, embracing a wide range of facts and deductions, and, for its full elucidation, demanding a distinct work. In a concise elementary treatise, it is impossible to exhibit this subject in a satisfactory manner, and in the present instance, drawing near our extreme boundary of space, we have the alternative, either of omitting, entirely, this part of the subject, or of giving, in the shortest terms, a few of the most important conclusions, to which the labors of many philosophers have conducted us; we have chosen the latter course and shall be constrained by our limits to omit most of the usual references to authorities, most of the names of authors and discoverers, and all the discussions on controverted and unsettled topics.

I. GERMINATION.

1. *The cotyledons of the seed are mainly farinaceous*; † the coraculum contains the rudiments of the future plant, viz. the rosetel and the plumule.

* Ann. of Phil. N. S. Vol. vii, p. 365.

† Containing also sugar, gum, mucilage and albumen.

2. *In a dry place, especially if cold, the vitality of the seed lies dormant*; it is awakened by moisture, heat and air; the best temperature is from 60° to 80° ; it varies with different plants; vegetable life is not quickened below 32° and it is destroyed at 212° . *Oxygen is indispensable*; a little chlorine dissolved in water, favors germination, by liberating oxygen; it will not commence, in vacuo, or in the gases deadly to life.

3. *Intense light* is unfavorable*, and it is often accompanied also by too much heat; seeds, in a mellow soil, a few inches from the surface, are in a favorable situation to germinate, because they have moisture, air and sufficient warmth.

4. *The soil is not indispensable*; for, seeds germinate readily on a moist sponge or in other situations, out of the ground, where they have air, moisture and warmth; seeds, buried deep in the earth, do not germinate; they may have moisture, but they have not air nor always sufficient warmth; innumerable seeds of innumerable kinds lie buried in various soils, for every new exposure of soil brings a new crop of plants.

5. *In germination, oxygen gas is absorbed*, and an equal volume of carbonic gas is evolved, as may be seen when germination takes place under a bell glass;† something besides carbon is removed, for there is a loss of weight of $\frac{1}{3}\frac{1}{4}$ or $\frac{1}{3}$;§ it may be moisture.

6. *The farinaceous and albuminous matter of the cotyledons becomes saccharine, and furnishes nourishment to the corculum*; first, to the rosette, which, whatever may be the position of the seed, seeks the earth, and next, to the plumule, which, in the like manner, invariably tends upward;|| the remains of the cotyledons fall off when the rosette can draw support from the ground, and the plumule and its young leaves from the air.¶

2. RESPIRATION.

1. *The materials of the juices of plants, drawn from the earth by the roots, pass up through the common vessels in the wood, circulate in the leaves, there receive the influence of the light and air, and*

* According to M. Leuchs, ripe seeds have never been obtained in darkness; an etiolated plant becomes green in 4 or 5 hours in the light; the light of a lamp produces greenness in plants, and they tend toward it; there is most solid matter in those that have had the light, and it is supposed that the nights would be fatal to plants, were it not for the light of the moon and stars. Eng. Quar. Jour. No. 14, N. S. p. 437.

† This is proved by causing germination to take place under a bell glass.

‡ Proust.

§ Thomson.

|| Both, if opposed, will contort themselves, in all imaginable ways, to accomplish the object.

¶ We have already mentioned the changes that occur in malting; see p. 410, of this volume, note and p.

then return through the proper vessels in the interior bark, to be assimilated and converted into the various principles appropriate to the plant.

2. It has been already stated, (p. 199, Vol. I,) that *in the direct solar ray, green leaves decompose or absorb carbonic acid, and emit oxygen gas* in equal volume; the same agency is exerted in water, containing carbonic acid, and if, in either case, there is none present, no oxygen gas is evolved;* beautiful trees grow on rocky mountains, deriving their carbon chiefly from the carbonic acid gas in the air.

3. *In the dark, the leaves evolve carbonic acid*, some say in volume equal to that of the oxygen given out in the light; but Dr. Thomson and Sir H. Davy are of opinion, that, agreeably to the original experiments of Dr. Priestley, the balance is in favor of the oxygen; on this question there is not unanimity, but the evidence appears to sustain the early opinion.†

4. Carbonic acid gas is always injurious to vegetation, unless it is absorbed and decomposed; it aids vegetation, if it does not exceed $\frac{1}{15}$ or $\frac{1}{10}$ of the entire air.

5. *Nitrogen appears not to be absorbed,‡ from the air*, and when that principle exists in plants, it is probably derived from the soil.

3. NUTRITION.

1. *Plants can vegetate with only air and moisture*; some plants may be even suspended in the air and retain their vitality;§ others will vegetate in siliceous sand, moistened with distilled water, as was the case with the willow tree of Dr. Hales;|| oats vegetate well on cotton, floating in a glass of pure water, and bulbous roots in water alone.

Water contains two of the elements of plants, oxygen and hydrogen; the atmosphere may afford oxygen, (and nitrogen also, if we may suppose with some that it is sometimes absorbed,) and its *carbonic acid*, which, although small in quantity, is constantly renewed, *supplies a large part of the carbon of plants*.

Sprigs of mint and of other plants, vegetating in air, which, by respiration or combustion, has been contaminated by carbonic acid gas, will restore the oxygen, by absorbing and decomposing the carbonic acid. Light is necessary to this effect, and plants growing in distilled water in the light and air, increase their quantity of carbon; but when growing in the dark, in the same circumstances, in other respects,

* According to Saussure, some oxygen gas is absorbed by the plant.

† Vol. i, p. 373.

‡ The opposite opinion has been maintained.

§ For instance, the fig trees, *Ficus elastica*, suspended four years, and the *Ficus australis*, ten years, in the Botanical Garden at Edinb. and still sending forth shoots and leaves; they were seen by Prof. Griseb., suspended from the ceiling.

|| See Ure's Dict. 3d Eng. edition, p. 784.

the carbon is diminished. Oxygen is necessary to the growth of flowers ; they perish without it.

2. Although plants derive most of their support from air and water, *their qualities are greatly influenced by the soil*, and the matters which exist in it ; from this source do they derive the salts, earths,* alkalies, and iodine, and even the metals which they contain.†

3. Perhaps none of *these things* act as food to the plant, but they *may excite its vital power*, and they certainly modify its properties ; plaster of Paris and lime may act as stimulants as well as materials, and all animal and vegetable manures,‡ consist of the elements which we find in plants.

4. *It is obvious*, from all that has been stated, *that* besides the carbon, hydrogen and oxygen, which are the invariable elements of vegetables, and the nitrogen, which is essential to some of them, *there are other elements and compounds*, that are found in them, more or less.

These are the alkalies ; the earths, lime§ and silica, and rarely magnesia and alumina ; several mineral acids in the native vegetable salts ; iron and manganese ;|| phosphorus and sulphur ; iodine ; and bromine, in the saline form, has been found in plants connected with saline sources. Silica appears to be essential to the firmness of the hollow grasses, such as wheat and oats, and it exists in the epidermis of the East Indian bamboos, in such quantity as to strike fire with steel ; there is also a siliceous concretion in the hollow of the bamboo, called by the East Indians, tabasheer.

As vegetable putrefaction is governed by the same principles as animal, what we have to state as to the nature and causes of these changes may be given in connexion, at the end of the chemistry of animal substances.

CLASSIFICATION OF VEGETABLES,¶ upon the proportions of oxygen and hydrogen.

1. *Principles having more oxygen in relation to the hydrogen, than is necessary to form water* ; instances—all the vegetable acids except the acetic.**

* Schrader's experiments which implied that earths and salts might be introduced by atmospheric dust, appear not to be fully accredited.

† Dr. Hare ascertained that metallic solutions may be speedily absorbed into plants so as to kill both them and insects feeding upon them. Am. Jour. Vol. xix, p. 172.

‡ Saussure on Vegetation ; Thénard's abstract in his Chemistry ; Dr. Priestley on Air ; Davy's Agricultural Chemistry, and Murray's and Turner's Chemistry.

§ It is rare to find a plant without lime ; the sal soda is said to be the only exception ; it contains a good deal of iron and .18 of magnesia, which earth exists in the fuci also.

|| Gold, doubtless accidental, was cited by Kunckel and Sage ; I am not aware that any modern analysis has confirmed the observation. Manganese has been found in pine, calendula, green oak and fig tree.

¶ See page 394 of this volume.

** Whose oxygen and hydrogen are exactly in the proportions to form water.

2. *In exact proportions to form water*; instances—sugar, molasses, honey, manna, starch, amygdine, hordein, gum, mucilage, lignin, pyroxylic spirit.

3. *Substances containing more hydrogen than, with the oxygen, is necessary to form water*; instances—vegetable alkalies, oils fixed and volatile, camphor, resins and resinous bodies, caoutchouc, wax, alcohol, ether, the natural bituminous substances.*

4. *Substances which, probably, do not belong to either of these classes*; coloring matter, tannin, gluten and its varieties, yeast, albumen, and most if not all of the imperfectly ascertained bodies.

II. ANIMAL BODIES.

General views.

1. *As vegetable substances are derived from the mineral, so the animal come from the vegetable*; no elementary or undecomposed body is therefore found in either, which does not exist in earth, water, or air.

2. In general, *the arrangements of animal and vegetable matter are*, either not at all or very *imperfectly, imitated by art*, because the principle of life and the action of organs greatly modify, and sometimes suspend or reverse, the chemical action.

3. *Animal substances*, in particular, *are the result of very delicate vital processes* and of a complicated organization; the balance of affinities is easily disturbed, by chemical agents, and we are constantly in danger of altering or subverting their constitution.

4. In general, *the composition of animal bodies is similar to that of vegetable*; both contain carbon, hydrogen and oxygen; but carbon predominates in the vegetable, hydrogen in the animal kingdom.

5. In the latter, there is less oxygen, as animal substances afford less acid, in their decomposition; some animal bodies, as jelly, are however more prone to the *ascendent* than to the putrefactive state.

6. *Most animal bodies contain nitrogen*, in abundance, while most vegetables contain none of it; it exists however in some of the latter, as in the fungi, in gluten, in mustard, cabbage, and generally in the cruciferous and papaveraceous plants, and in the nitrous.

7. *Phosphorus and sulphur also exist*, in considerable quantities, in animal bodies, but more sparingly in vegetable.

* Of these I have not thought it necessary to give any account, among the vegetable bodies, for although most of them are probably of vegetable origin, they belong rather to the science of mineralogy, and are treated of in a distinct course of lectures, in the institution, for which this work is more particularly designed. Birdlime is mentioned, by some writers, as bearing some analogy to caoutchouc, and I had drawn up a notice of it, but have omitted it, in compliance with general custom, and because the space was needed for other subjects.

8. *Nitrogen, Phosphorus and Sulphur, are the principal things which modify the products from animal substances, when they are decomposed, either naturally or by art.*

9. *Phosphuretted, sulphuretted, and carburetted hydrogen gases, empyreumatic oil, prussic and acetic acids and ammonia, are the chief products which, by putrefaction or by fire, arise from this peculiar constitution; and after heating in close vessels, charcoal remains with phosphoric salts.*

10. *Animal carbon is frequently brilliant, and, in appearance, almost metallic; its clarifying powers exceed those of the vegetable carbon; it is of difficult combustion and is much involved with phosphates, and with oxides of iron and manganese.*

11. *Carbonic acid and water are also evolved in the destructive distillation of animal bodies; carbonic oxide, as well as hydrogen and nitrogen, or their products, are also liberated.*

12. *Nitrogen is separated from animal muscle by the action of diluted nitric acid,* and if the experiment be properly conducted, the acid is not decomposed. Nitrogen, as has been already stated, exists in all the vegetable alkalies.*

13. *In general, animal bodies, when dead, are much more prone to putrefaction than vegetable, and the odor which they exhale is much more fetid; oils and cholesterine† do not contain nitrogen and do not putrefy; animal matters rarely run into the vinous‡ or acetous fermentation.*

14. *A few vegetable substances putrefy like animal bodies, as cabbage, fungi, gluten, &c. and they contain nitrogen.*

15. *With respect to the origin of the elements of animal matter, the carbon, hydrogen and oxygen are obtained from obvious sources, in vegetables and in air; if the nitrogen of animals is not derived from the air, it probably enters more abundantly into the original constitution of vegetables than was formerly supposed; still the supply of nitrogen for animals, from vegetables of known constitution, is insufficient, especially, as several of the azotized vegetables, are poisonous; unless therefore nitrogen is absorbed in respiration, its origin in animals is not well accounted for, especially as it is equally abundant in graminivorous and herbivorous as in carnivorous animals; it may, possibly, be a compound substance, and then it might be formed from its elements.*

• *Phosphorus and sulphur exist in vegetables, but it would seem in quantities insufficient, at least, in the case of phosphorus, for all that is found in animals.*

* Vol I, p. 193.

† A substance resembling spermaceti; it is found in the bile and biliary concretions

‡ Milk affords an intoxicating fluid.

ULTIMATE AND ELEMENTARY ANALYSIS.

In relation to this topic, all that was stated respecting vegetables, (p. 392,) is applicable to animal bodies. Thus, by putrefaction or by fire, the hydrogen and nitrogen may combine, in such a manner as to produce ammonia, although in the natural state of animal bodies, it exists only sparingly in them.

The accurate elementary analysis is conducted upon the same principles and in the same manner as has been described in relation to vegetables.* In the bodies that are neither acid nor oleaginous, the hydrogen is sufficient to convert their oxygen into water, and their nitrogen into ammonia, and there is much carbon besides.

It is considered as probable that, in animal acids, the oxygen and nitrogen are in excess in relation to the hydrogen, that is, they are more in quantity than is necessary to form water and ammonia; that in the oils the hydrogen is, in these respects, in excess, and that in other principles, the proportions may not correspond with either of these statements.

That the elements of animal matter are united in equivalent proportions, is not yet so fully established as in the case of vegetables, but as it has been proved to be true in several cases, there can be no reason to doubt that this is generally the fact.

PROXIMATE PRINCIPLES OF ANIMAL SUBSTANCES.

1. *Those hitherto ascertained are fewer than in vegetables; they are obtained by simple processes,* which probably give them, nearly as they existed in their natural state.

2. Instances; melt *solid fat* to separate it from the membranes, &c.; boil a bone, the *gelatin* will be dissolved, and if strong, it will concrete or gelatinize, on cooling, and the *oil* will float; break an egg, the white is nearly pure *albumen*, and becomes solid by a moderate heat; blood, by mere repose, becomes a clot, and the serum which is chiefly albumen, spontaneously separates, and by heat, coagulates; the clot, if carefully washed, affords a white fibrous matter analogous to the basis of muscle; it is *fibrin*, &c., as will appear under the various articles.

SEC. I.—GELATIN.

ORIGIN—IMPORTANCE.

1. *One of the most important and most distinct of the animal principles; and so abundant that there is scarcely any organ without it.*

* Reference may be had to the authorities cited p. 393, note, and also to Mr. Forrett, in the Phil. Trans. 1815; Dr. Prout, in 1827; Ann. de Chim. et de Phys. Vol. v, p. 290, and Ann. de Chim. Vol. xcvi, p. 53.

2. *The skin affords more of it than any other part*; it is contained largely in the membranes, tendons, aponeuroses, ligaments and cartilages; even in the bones and "hard bony horns," and generally in all white solids, and most of the soft white parts.* In the proportion of from 2 or 3 to 7 or 8 per cent., it forms the natural cement of shells.

GELATIN.

I. EXTRACTION.

Gelatin is obtained, simply by boiling the substances containing it in water, for more or less time, according to the nature of the material.

II. PROPERTIES.

(a.) *The solution is transparent* and white, or only slightly colored; if gently evaporated to a sufficient degree, it *gelatinizes*, that is, it fixes into a soft tremulous solid, of which calves foot jelly is an example; it is a hydrate and, by mere warming, dissolves again in its own water.

(b.) *By continued gentle evaporation, it concretes*, on cooling, into a firm solid, with a vitreous fracture, commonly of a brown color,† and only slightly transparent.

In various degrees of consistence, it is known in the arts, by the names of glue, size, portable soup, isinglass or ichthyocol, &c.

(c.) *Properties of dry gelatin*; if pure, it is insipid and nearly transparent and colorless.‡

(d.) *In water, it swells and becomes elastic*; with heat, it dissolves, forming a solution like the original one, and the solid glue may be recovered by another evaporation; these desiccations and resolutions may be indefinitely repeated, without change of properties; this distinguishes gelatin from albumen, which, after coagulation by heat, is no longer soluble.

(e.) *Tremulous gelatin dissolves in a little warm water*, and again gelatinizes on cooling; if recently congealed, it dissolves in cold water.

(f.) Dry gelatin, 1 part, dissolved in 100 of hot water, gelatinizes on cooling; but with 150 of water, although gelatinous, it does not concrete on cooling.—*Bostock*.

(g.) *When solid and dry, gelatin is indestructible and unalterable by the air*; in solution, it soon putrefies, some say with a previous production of acetic acid, (but this is questioned,) and it finally exhales ammonia.

(h.) *Insoluble in alcohol*, although not readily precipitated by it from an aqueous solution, which however is made turbid by alcohol,

* Aikins.

† As we see it in the glue of the carpenters.

‡ The common glue is opaque and brown from impurities.

but unless a very large quantity is added to a strong solution of gelatin, it becomes again clear. Alcohol, in great excess, forms a permanent precipitate.

(i.) *Heat causes dry gelatin to swell and curl like horn*; it gives out an ammoniacal oily liquor, leaving, especially in close vessels, a bulky coal, equal in weight to about $\frac{1}{8}$ of the gelatin; when ignited in the open air, this coal burns away almost completely, although not very readily, and leaves 1.5 gr. of phosphate of soda and phosphate of lime, for every 56 grs. of coal.

(j.) *Gelatin is equally soluble in acids as in water.*

1. *Nitric acid, diluted and cold, dissolves it, apparently without alteration*; it is thus separated from albumen, particularly as it exists in cartilage.

The nitric solution is of a pale yellow, deepening by evaporation.

Strong nitric acid decomposes gelatin, and is decomposed by it; nitrous gas, nitrogen, and sometimes even sparks and flame, are evolved; if the action has not gone too far, oxalic and malic acids are also produced. The tremulous gelatin of fish glue, dissolves very readily in acids.

2. *Cold muriatic acid easily dissolves gelatin*, and the solution keeps for months; this acid separates it, completely, from the dense albumen of animal compounds. Still, dilute muriatic acid dissolves out the phosphate of lime from bones and leaves the gelatin,* retaining the shape of the bone.†

3. *Sulphuric acid dissolves it more slowly and less perfectly. It converts gelatin into a species of sugar*; powdered glue was mixed with twice its weight of strong sulphuric acid, and after one day, three times as much water was added and boiled for 5 hours, the water being renewed as it evaporated; the excess of acid was removed by chalk, and the filtered and evaporated fluid, in the state of syrup, being left to itself for one month, afforded crystals of sugar. After washing with weak alcohol, and after a second solution and crystallization, the crystals were firm and cracked between the teeth like sugar candy;‡ still this sugar does not dissolve in alcohol nor ferment with yeast; it dissolves in nitric acid and affords ammonia by destructive distillation.

4. *Common vinegar, with a gentle heat, dissolves isinglass, and forms a very useful cement.*§

* The two facts stated in this paragraph are not inconsistent; the acid prefers the phosphate of lime to the gelatin.

† For Mr. L. Doolittle's notice of the extraction of gelatin from bones, in Paris, see Am. Jour. Vol. i, p. 171.

‡ For other particulars, see Braconnot's memoir, Ann. de Chim. et de Phys. Vol xii, p. 113.

§ Henry.

Glue, dissolved in water, is not affected by sulphuric or muriatic acid. Alkalies give no precipitate in the acid solutions of gelatin.

(k.) *Hot alkalies, when caustic, dissolve it with great ease*, forming a brownish viscid substance, unlike soap and not precipitated again by acids; fibrin, albumen, and most soft parts of animals, on the contrary, form a soap which curdles with acids.

(l.) *Metallic solutions*; among them, nitrate of silver and muriate of tin produce a slight opacity, and muriate of gold gives a small portion of a dense precipitate.*

(m.) *Tan or tannin is the most delicate and useful precipitant of gelatin*; an infusion of 1 oz. of nut galls to 1 pint of water precipitates 1 part of gelatin from 5000 of water.† *Strong solutions of gelatin and tannin give a dense coagulum*, compressible by the fingers and very extensible by pulling; it smells like new tanned leather, and appears to be very nearly like that substance; it is impervious to water, insoluble in it and imputrescible; an infusion of any astringent vegetable, as catechu, galls or oak bark, gives a precipitate with gelatin.‡ (See p. 446 of this volume.)

Albumen is also precipitated by tannin, but if the solution is dilute, not till after some hours, so that an immediate precipitation in a diluted fluid indicates gelatin. Concentrated albumen gives an immediate precipitate.§

(n.) *Composition of gelatin according to Gay-Lussac and Thénard*; the analysis was performed by chlorate of potassa.

Carbon,	-	-	-	47.88
Oxygen,	-	-	-	27.21
Hydrogen,	-	-	-	7.91
Azote or nitrogen,	-	-	-	17.

100.00

Dr. Henry gives the following equivalent numbers as those that correspond nearest to this analysis; carbon, 15 equiv. = 90, oxygen, 6 = 48, hydrogen, 14, nitrogen, 2 = 28 = 180. It is remarkable, that Dr. Prout found in albumen the same elements and in the same proportions.

* See a table in Thomson's Chem. Vol. IV, for more effects of metallic tests.

† The filtered aqueous extract of rhatania is a good form for preserving this test.

—Henry.

‡ For exhibition, a strong infusion of galls may be added to a dense one of glue or isinglass, stirring it gently with a glass rod, around which it will collect in a pretty firm mass; this may be slipped off into the palm of the hand and pressed to free it from water. We begin to extend it by pressing and gentle pulling, and with the aid of an assistant, it will rope out several yards in length; when dry it will be brittle.

§ The coagulation of albumen by heat will always distinguish it from gelatin.

III. Uses.*

1. *Gelatin is highly nutritious*; it forms the most important ingredient in soups and broth, and is diffused more or less, through the greater part of our animal food. When evaporated with care, it retains much of the flavor of the substance which afforded it.

2. *Joiners' glue* is the concentrated gelatinous extract of the skins, ears, and other firm parts of mature animals; the skin of the Rhinoceros affords an admirable glue. *The size of the paper makers is a dilute glue*; it fills the pores of the paper and prevents the ink from spreading.

3. *Portable soup*.—Meat is boiled; the fluid is skimmed and allowed to cool, to separate the oil which floats; the extract, after being boiled, clarified by whites of eggs, and strained through flannel, is evaporated to a very thick paste and spread, rather thin, upon a smooth stone, and then cut into cakes and dried in a stove till it becomes brittle; the cakes, if dry, will keep four or five years, and when they are to be used, they are redissolved.

Calves foot jelly.—The preparation is similar, only the solution is evaporated to such a state that, on cooling, it will form tremulous gelatin, and while it is fluid, wine, lemon juice, sugar, &c. are added for the flavor, and sometimes dyeing colors, to produce an agreeable hue.† Gelatin is said, by Berzelius, not to exist in any of the healthy animal fluids.

Fish glue, (*ichthyocol*), is extracted from the sounds or air bladder of a fish, of the genus *Acipenser*; usually spoken of as a sturgeon.

Chlorine converts gelatin into a kind of animal membrane; it takes hydrogen from it and forms muriatic acid.

4. **TANNING**.—The skins are freed from horns, hoofs, muscle, fat and hair; tools are used in cutting, scraping, shaving, &c. and chemical agents are employed, especially, lime or acids, derived from the fermentation of rye, or barley, or bark, or diluted sulphuric acid; or incipient putrefaction, to favor which the skins are laid in heaps.

The skin, being little else than gelatin entangled in fibrous matter, is now subjected, in vats, to the action of oak bark, hemlock, chestnut, or other materials containing tannin. It is applied both in substance, by stratifying the skins with the ground bark, and by the action of water which dissolves out the tannin and conveys it to the glue. At first a cold and afterwards a hot infusion is applied; the ground bark is boiled or simmered in water and applied to the skin at about blood heat; if much hotter, it injures the leather. The process of

* For a particular account of the varieties of gelatin and their mode of preparation, see Alkin's *Diet. article Gelatin*, also Thomson's *Chemistry*, Vol. iv; Hatchett's *Memoirs in Phil. Trans.* 1797 and 1800; Johnson's *Animal Chem.* Vol. i, p. 311, and Gay-Lussac, *Cours*, Vol. ii, p. 8.

† Saffron, cochineal, &c.

tanning has been shortened from two or three years for thick leather, to six or eight months, and from twelve or eighteen months to two or three, for thin leather. On small quantities, it may be made effectual in a few days or even hours, although the leather is not thought to be so good. I have a piece of goat skin, well tanned, curried and colored, which was on the body of the living animal early in the morning, and the same evening, at the distance of fifteen hours, was worn in finished shoes, in the state in which I now have it.*

It is my object in this place, merely to point out the principle of this important art; the details of the modern improvements, would occupy too much space in a concise work.†

Leather is very indestructible; it lasts a long time under water as in water pumps, and still longer in a dry air as may be seen in many ancient relics.‡

SEC. II.—ALBUMEN.§

Remark.—The white of an egg contains albumen in the purest form in which it is known; it is still combined with some salts, with sulphur, and with a little soda; even when fresh, it contains free soda, and turns the delicate blue vegetable colors, as syrup of violets, green; the washings from the coagulated albumen, evaporated to $\frac{1}{4}$, turn turmeric brown.

I. PROPERTIES.

(a.) *By agitation with water, it is perfectly soluble in that fluid, in every proportion, and forms a glairy fluid.*

(b.) *Coagulable by heat, even by hot water; this is its characteristic property; the coagulation takes place at 160° F., and at 212° a solution in water of $\frac{1}{1000}$ of albumen coagulates.*

(c.) From 100 grs. of thin slices of coagulum, $4\frac{1}{2}$ grs. of an uncoagulable brownish viscid fluid ooze out, and after a gentle continued heat, the residuum weighs $15\frac{1}{2}$ grs.; $\frac{1}{1000}$ are therefore water.

(d.) *Albumen, when coagulated, weighs just as much as when fluid; its fluidity has been imputed to the soda, and in the coagulation this alkali is supposed to pass to the water of the solution, or to acids or alco-*

* On the testimony of a gentleman of high character in Boston, in a personal communication to the author.

† See Chaptal's Chem. Philos. Mag. Philos. Trans. Ann. de Ch. et de Ph. Ure's Dict. One of the most curious of the mechanical improvements connected with tanning, is the splitting of the hides in the direction of their length, by which two skins are made out of one; it is done by a machine with perfect accuracy, as in the establishment of the Messrs. Gilbert, at New Haven.

‡ For instance, the saddle of Henry IV, in Westminster Abbey, Lord Darnley's boots and other personal articles in Holyrood House, Edinburgh.

§ This is the Latin for white of an egg. It is not a classical name but one introduced by physiologists.—Thomson.

due of 74.5 gra., of which 63.25 were coal, and the remainder phosphate of lime, phosphate of soda, and a little carbonate of lime.

(x.) *Composition*, according to Gay-Lussac and Thénard, carbon 52.883, oxygen 23.872, hydrogen 7.540, nitrogen 15.705 = 100.

The nearest approximation to chemical equivalents is, in the opinion of Dr. Henry, to carbon 17 equiv. = 102, + oxygen 6 = 48, + hydrogen 13, + nitrogen 2 = 28 = 191, which, except in the nitrogen, does not differ a unit from the ratios found by Gay-Lussac and Thénard. Dr. Prout's analysis* gives, substantially, the same composition to albumen as Gay-Lussac and Thénard assigned to gelatin; it was carbon 50, hydrogen 7.78, oxygen 26.67, nitrogen 15.55, corresponding to 15 equiv. = 90 of the first, 14 of the second, 6 = 48, of the third, and 2 = 28 of the fourth, = 180; the difference, 11, being made up of 2 equiv. less of carbon and 1 of hydrogen. Dr. Prout has noticed what he calls an incipient albumen, supposed to be in progress towards its perfect state.†

II. NATURAL SOURCES AND USES.

(a.) *Albumen is the first of the soft parts of animals that is formed*, and the other parts are produced from it.

(b.) *It is the basis of cartilage, nails, shell, horn, and hair*; it enters into the composition of the vessels that convey the fluids; it exists in skin, glands, membrane, bone and muscular fibre, and is therefore found both in the solid and fluid form.—Hatchett.

(c.) *There are varieties of albumen, as there are of gelatin*; in abundance, it is next after that principle in the animal system; it forms the basis of the serum of blood; of the coagulable part of milk, (cheese;) of the white of eggs, and exists largely in the liquor of dropsy; it is found in the chyle, and in the eye, especially in the vitreous and crystalline humors; in the fluid of burns and blisters; in that of the pericardium; of the ventricles of the brain, and in many other animal fluids, especially those secreted by the serous membranes.

(d.) *It is very nutritious, and enters largely into our aliment.*

(e.) In consequence of its coagulating by heat and by acids, *it is used to clarify liquors*,‡ and the syrup of sugar; for the latter purpose blood is employed; in cider and wine, the albumen is coagulated by the vegetable acids and by acidulous salts.

(f.) It has been already stated that *albumen exists in many of the cruciform plants*, e. g. cress, scurvy grass, cabbage, &c. and in

* Ann. Phil. Vol. xiii.

† Ann. Philos. Vol. xv, p. 25, 274.

‡ Dried albumen, prepared from blood, or better from whites of eggs, is used in France for clarifying wine. Eng. Quar. Jour. Vol. xv, p. 395.

those vegetable fluids that enter into the vinous fermentation, without the addition of yeast;* found also in starch water, which grows turbid by heat, and deposits albumen.

(g.) *A solution of whites of eggs, in water, is used by leather dressers to render their leather supple*, and it is employed to remove contraction and rigidity of the tendons; the alum curd of Riverius, used to remove inflammation of the eyes, is made by beating in a basin whites of eggs with a piece of alum.†

* * * * *

It is not my intention to attempt a minute account of animal bodies, but under each proximate principle I will mention the most important parts in which it exists.

PARTS OF ANIMALS CONTAINING GELATIN OR ALBUMEN, with other principles.

1. **BONES.**—It has been already stated, that they contain gelatin and phosphate of lime, to which add phosphate of magnesia and carbonate of lime, beside oil and marrow, (which is a variety of oil,) and occasionally some other things.

Diluted nitric or muriatic acid, as before mentioned, dissolves out the earthy matter and leaves the gelatin in shape; it resembles coagulated albumen, and being first formed, it is the mould in which the earthy matter is cast. I shall not repeat what has been said of the products from bone by fire.‡

Composition of some varieties of bones.

1. *Ox bones*; animal matter 51, phosphate of lime 37.7, carbonate of lime 10, phosphate of magnesia 1.3.§

2. *Dry ox bones* gave very nearly the same result; the carbonate of lime was 3.85.

3. *Human bones*; gelatin or cartilage 32.17, blood vessels 1.13, (=33.30 animal matter,) phosphate of lime 51.04, carbonate of lime 11.30, phosphate of magnesia 1.16, fluuate of lime 2; soda, muriate of soda, water, &c. 1.20=100.

4. *Enamel of ox teeth* gave only 3.56 cartilage, but there was 81. phosphate of lime, 4. fluuate of lime, 7.10 carbonate of lime, 3. phosphate of magnesia, 1.34 soda, salt and water.

* Seguin inferred that it is the true principle of fermentation; that it possesses three degrees of solubility, and that the more soluble the more powerful it is.

† Nicholson's Dictionary.

‡ Vol. i, p. 226 and 436.

§ Vauquelin and Fourcroy.

5. *Human enamel*, (*analysis by Berzelius*,) gave phosphate of lime 85.3, carbonate 8, fluato of lime 3.2, phosphate of magnesia 1.5, soda, salt, &c. 2, but no cartilage. (*Analysis by Pepys*;) phosphate of lime 78, carbonate 6, loss and water 16. Dr. Henry suggests that this loss may be owing to gelatin dissolved in acids, and not capable of being again precipitated by alkalies.

6. *Teeth in substance*—average of 3 analyses, of roots—teeth of adults and of children—phosphate of lime 61.3, carbonate 5.3, cartilage 22.6, loss 10.6.

2. **SHELLS**; the coverings of the testaceous animals. In shells, the carbonate of lime predominates, as the phosphate does in bones; in those of molluscous animals, oysters, clams, muscles, &c. carbonate of lime is cemented by a little gelatin;* in mother of pearl shells, coagulated albumen, in the form of membranes, intervenes between the layers of carbonate of lime; the pearl itself has the same structure, and its beauty is owing to a peculiar reflection of light.†

3. **CRUSTS**—the covering of the crustaceous animals, such as lobsters, crabs, &c. In these, a little phosphate of lime is united with the carbonate, and both are cemented by a cartilaginous matter resembling coagulated albumen. Egg shell has a similar composition midway between that of bones and of shells.

4. **HORNS, HOOFS, NAILS AND SCALES**.—Horns contain only about 1.5 of earthy matter, and but half of this is phosphate of lime; the substance of the horn is cartilaginous, like coagulated albumen; it is well known that it can be softened and moulded into any form, as in the manufacture of combs. There is a little gelatin in horn, and the most in the softest. The horn of the buck and hart is principally indurated gelatin, with a little phosphate of lime, and is therefore somewhat analogous to bone. The coverings of tortoises are similar to horn, and so are hoofs, nails, talons and claws of birds and animals, and quills, (particularly the tube part,) and the horny coverings of insects; all these are coagulated albumen with a little phosphate of lime. The scales of serpents and of amphibia are much like horn; those of fish are composed of layers of membrane and phosphate of lime.

5. **CARTILAGE**; this has been generally considered as coagulated albumen, nearly pure. For some peculiarities of the cartilage of the *Squalus peregrinus*, see Henry, Vol. ii, p. 510.

6. **HAIR, WOOL AND FEATHERS**.—Hair is indurated albumen, insoluble in cold water, but soluble by the aid of a regulated heat and

* Some prefer to call it indurated albumen.

† See an interesting illustration of this subject in Count Bournon's *Mineralogy*; he traces beautifully the analogy between the animal and mineral carbonate of lime.

pressure; nitrate of silver is blackened by the solution, and hair is blackened by the nitrate.

Alcohol, by maceration, dissolves out of hair an oily matter, in which its color resides; there are also some portions of silica, carbonate and phosphate of lime, and oxides of iron and manganese. Wool* is only a variety of hair, and feathers are similar.

7. SILK has been but imperfectly examined; the varnish is soluble in boiling water and in soap and the soap leys;† it forms .23 of the silk.‡ Nitric acid produces with it a bitter principle. A weak acetic acid, secreted by the silk worm, was formerly called the bombyc acid, from bombyx.

8. THE SKIN; tendons; ligaments; membranes.

(a.) *The epidermis or scarf skin*, the outer skin, which is raised in blisters and in burns, appears to be composed of coagulated albumen.

(b.) *The rete mucosum*, or mucous substance, or reticular tissue, lying between the epidermis and the cutis vera; its composition has not been precisely determined; in this the color of the negro resides, and Dr. Beddoes, having first made the trial on the fingers, then immersed, for some time, the feet of a negro in an aqueous solution of chlorine; they were rendered almost white, but in a few days the color returned in full intensity.§

(c.) *The cutis vera*.—This is a fibrous membrane, and when long boiled in water, it is nearly all dissolved in the form of gelatin.

Tendons or sinews, by long boiling, give a solution of gelatin; they are similar to skin. *Ligaments and membranes* are partly soluble in water, but they contain a substance not thus soluble; they are composed, apparently, of gelatin and albumen; the serous membranes furnish no gelatin by boiling.

9. MILK.—The chief constituent of milk is a principle analogous to albumen.

By repose, the cream rises to the surface. It contains whey 92, cheese 3.5, butter 4.5. Butter will be named again, under the oils. In churning, the temperature rises 3 or 4 degrees, and oxygen is absorbed, but it is not necessary to the separation of the butter, as it takes place when air is excluded. Butter is made in some countries by churning the milk; but the product is not so good as that from cream alone.

* Wool is enveloped in a peculiar oily matter called the yolk, from which, in the manufacture of cloth, &c. it is freed by scouring.

† By the successive application of weak leys, alcohol and dilute muriatic acid.—Murray.

‡ Ann. de Chim. Vol. lxxv.

§ Dr. Thomson in Edin. Encyc.

Milk, with or without the cream, is *coagulated by acids*,* by many salts, by gum, sugar, and various vegetable juices, and by the gastric fluid. It has been said that milk does not coagulate by heat, but this arises from its dilute state, for as the water evaporates, a film of coagulated albumen appears, and the whole of that principle may in this way be removed. The cause of the coagulation, especially by rennet, is obscure; a piece of the salted inner stomach of the calf, of the size of a half crown, will coagulate milk enough for a cheese of 60 lbs.—*Henry*.

The albumen of milk properly pressed, salted, and preserved, is cheese; but it is not rich unless the butter remains with it, and therefore good cheese cannot be made of skimmed milk. That fluid consists of water 928.75, cheese with some butter 28, sugar of milk 35, muriate and phosphate of potassa 1.95, acetic acid, acetate of potassa and acetate of iron .6, and earthy phosphates .3. After withdrawing the cheese, the rest is whey,† which will be mentioned again.

It has been already mentioned that a spiritous fluid is formed from milk, and called koumiss.‡ It is singular that the milk, after fermentation, contains as much sugar of milk as before; if there is no mistake, this is an exception to the laws of vinous fermentation.

10. Eggs.—The albumen which they contain has been already mentioned; if the entire egg weighs 1000 grs. the white weighs 604, the yolk 290, and the shell 106. By boiling, the egg loses .3 gr., the chief thing in which is soda,‡ and, by evaporation, the solution becomes decidedly alkaline; there are also present minute portions of carbonate, sulphate, phosphate and muriate of lime and magnesia.

The yolk, boiled hard and digested in alcohol, sp. gr. .807, until it takes up nothing more, becomes white and pulverulent, and approximates to albumen. The alcoholic solution is of a deep yellow and deposits, on cooling, a semi-fluid oil of that color, and some sebaceous substance; the oil containing the color of the yolk, is obtained separately, by distilling off the alcohol.

It is remarkable, that while the white contains sulphur, the yolk contains phosphorus, either free or in some unknown state; when the dried yolk is burned, the phosphorus becomes phosphoric acid, which forms a vitreous investment over the charcoal and screens it from combustion.

* The acetic acid, (called the lactic, when generated in milk,) is soon generated; spontaneously, in milk, and produces coagulation.

† For a notice of the controverted and uncertain principles, the caseous acid and oxide, I refer the reader to Dr. Henry's and Dr. Turner's Chemistry; to the Eng. Quar. Jour. Vol. vii, p. 391, and to Ann. de Chim. et de Phys. October, 1827.

‡ See Phil. Mag. Vol. xxxvii, p. 6.

The phosphorus is supposed to aid in some unknown way, in the formation of phosphate of lime in the bones of the chick.*

11. **CHYLE**—the fluid taken up by the lacteals from the small intestines, and poured, by the thoracic duct, into the blood, which it supplies with the nutritious part of food and thus preserves the system from waste.

It varies in its appearance; if drawn from a mammiferous animal, three or four hours after eating, it is white like milk, with a taste both salt and sweet. It soon coagulates spontaneously, and a firm coagulum is formed in twenty four hours. It resembles the albumen of milk;† the fluid that separates by being heated, affords more of it, and a copious precipitate of the same substance occurs, if the fluid is boiled with acetic acid; it is the substance which Dr. Prout calls incipient albumen. His analysis of the chyle of two dogs, one fed with vegetable and one with animal food, is annexed.

	Vegetable food.		Animal food.	
Water, - - -	93.6	- -	89.2	
Fibrin, - - -	0.6	- -	0.8	
Incipient albumen,	4.6	- -	4.7	
Saline matter, - -	0.8	- -	0.7	

There was also oil and sugar of milk. The character of the incipient albumen is not perhaps quite clear.‡

12. **MUCUS**.—It is so doubtful whether there is a distinct principle to which this name can be applied, that I do not give it a place among proximate bodies. Still, it is well to preserve the term as descriptive of the fluid secreted by numerous surfaces. We are best acquainted with it in the nostrils and mouth.

(a.) *Mucus of the nostrils*, when first secreted, is limpid and fluid, but becomes inspissated; dried on blotting paper, it becomes opaque, and transparent again by adding water; not coagulated by boiling water, but falls unchanged; coagulated by nitric acid, and by digestion is dissolved in it; hardened, but not dissolved, by the acetic acid; dissolved by potassa, ammonia being emitted; coagulated by tannin.

Composition.—Water, 936.7; mucous matter, 53.3; muriate of potassa and soda, 5.6; lactate or acetate of soda, 0.9; albumen and animal matter, 3.5 = 1000.

(b.) *Tears*; they are saline and alkaline, containing muriate and phosphate of soda, and free soda which turns the infusion of violets green; they contain a little animal matter, probably albumen, it was formerly regarded as mucus; the tears are chiefly water.

* Prout, Phil. Trans. 1822.

† Vauquelin thought it more analogous to fibrin or between fibrin and albumen. Ann. de Ch. Vol. xxxi.

‡ See Ann. de Ch. pp. 80, 81, and Ann. Phil. Vol. xv, p. 25.

(c.) *Saliva*.^{*}—Saliva evaporated, leaves a substance like gum; oyster liquor affords the same, and it is again soluble in water, but not in ether or alcohol. Saliva contains phosphoric and muriatic salts; chiefly muriate of potassa with the sulphate, phosphate, acetate and carbonate, and what is much more remarkable, the sulphocyanate of that alkali, (a variety of the prussiate,) which is thought to account for the production of a red color by saliva in a per-salt of iron,[†] and for those effects that have been attributed to a free alkali. This salt has been found in the saliva of the sheep, which contains also so much carbonate of soda as to effervesce with acids. Albumen is detected in saliva and in mucus, by galvanism only. 1000 grains of saliva afford only 120 of solid matter, of which, 20 grs. are saline.

Mucus exists also, in various other healthy and in some morbid secretions, as in the liquor of dropsy.

The salivary concretions, both in the glands and on the teeth, appear to be indurated mucus or albumen, with phosphate of lime.

13. HUMORS OF THE EYE.

(a.) *The aqueous and vitreous humors*.—According to Berzelius, the two fluid humors of the eye contain more than 98 per cent. of water, the rest being albuminous, alkaline, and saline matter.

(b.) *The crystalline lens* had 58. water, 35.9 peculiar matter, salts and animal matter soluble in alcohol 2.4, animal matter soluble in water 1.3, insoluble membrane 2.4. The lens is lamellar, the layers being more dense towards the centre.

14. *LIQUOR OF SURFACES*—for producing lubricity; it is very similar to the fluid of the pericardium, which, according to Dr. Bostock, contains water, 92, albumen, 5.5, mucus, 2, muriate of soda, 0.5; in the dropsy of the heart, the fluid has been found to consist of 988.3 water, 1.66 albumen, 7.09 muriate of potassa and soda, acetate of soda and animal matter, 2.02, soda, 0.28, and animal matter, soluble only in water, with a trace of phosphates, 0.35. Lymph, taken up by the absorbents, consists chiefly of water, with muriate of soda and albumen, coagulable only by galvanism.

15. *SYNOVIA*—the fluid that lubricates the joints, contains in 100 parts, water, 80.46, fibrous matter, 11.86, albumen, 4.52, muriate of soda, 1.75, carbonate of soda, .71, and .70 of phosphate of lime.

16. *PERSPIRABLE MATTER* consists, according to Berzelius, of water, 981.70, animal matter, 4.60, muriate of soda, 12.56, and soda, 1.14, = 1000. It is said also to contain free acetic acid, but this seems inconsistent with its containing also free soda.

^{*} Saliva contains osmazome and a little phosphorus, dissolved in fatty matter.

[†] Edin. Medical and Surgical Journal and Turner's Chem.

SEC. III.—FIBRIN, (FIBRINA, *Fibre*, *Muscular Fibre*, *Flesh*, *Animal Gluten*.)

1. *This is the fibrous part of animal muscle*; its exclusive peculiarity is to contract when stimuli are applied, and to relax again when they are withdrawn; upon this power, hitherto unexplained, depend the motions of the limbs of all animals.

2. *Muscle is minutely intersected by cellular web* and penetrated by arteries, veins, nervous fibrils and lymphatics; therefore the chemical composition of pure fibre cannot be precisely ascertained.—*Atkins*.

I. PREPARATION.

(a.) Foreign principles are, to a good degree, separated by long continued maceration and boiling, with alternate pressure and frequent renewal of the water; the muscle being previously cut into thin pieces.*

(b.) *Obtained† also by washing*, with cold water, a clot of blood, on a linen cloth, till it becomes white.

(c.) *By stirring the fresh blood of a large and mature animal till it coagulates.‡*

II. PROPERTIES OF FIBRIN.

(a.) *Solid, tasteless, inodorous, white, fibrous*;§ insoluble in water or alcohol; when newly obtained from blood, it is soft and elastic, and much resembles the gluten of vegetables.||

(b.) *The fibrin of muscle is partially transparent*; not ductile, but brittle, and less putrescent than the fibrin of blood; pure dry fibre is not very liable to putrescence and may be long preserved, by salts,¶ smoke, pyroligneous acid, &c.

* Mr. Hatchett macerated 3 lbs. of muscle for fifteen days in cold water, changed every day, pressure being also applied; he afterwards boiled it for five hours every day for three weeks, changing the water as before; and finally it was pressed and dried by the heat of a water bath.

† The concretions called *polypi*, found in the vessels of animals after death, are coagulated fibrin; the inflammatory or buffy coat of blood is owing to the same cause, and so is its spontaneous coagulation.

‡ A small branch of a tree, several times forked, held in a flowing stream of blood, and rolled between the hands, with the forked end downwards, will soon collect the coagulum; the color is removed by washing and the fibrin remains, resembling cotton or woollen yarn. In France, when they wish to preserve blood from coagulation, that it may be used in refining saltpetre and sugar, they stir it with osier brooms and thus collect the film around it; for the same purpose it is sometimes beaten with bunches of twigs.

§ The fibrous structure is discoverable by the microscope.

|| Whence the synonym *gluten*, which should never be thus used without the prefix animal.

¶ See note † Vol. I, p. 473.

(c.) *Contracts by heat and moves like horn shavings*, with the smell of burning feathers.

(d.) *With a stronger heat it melts and is decomposed*, yielding water, carbonate of ammonia, fetid oil, acetic and carbonic acids, and carburetted hydrogen gas.*

(e.) *Acids, in general, dissolve fibrin with facility.*

1. *By strong sulphuric acid, with heat, it is carbonized*; Braconnot states that muscular fibre, as free from foreign matter as possible, was dissolved in sulphuric acid, without changing color or evolving sulphurous acid gas, and being gently heated, some fat appeared on the cold fluid; after being boiled nine hours with water, the acid was saturated with chalk, and the extract that remained after filtering, smelled like osmazome,† (the odorous principle of roasted meat,) and the extract was several times boiled with alcohol, from which there fell a white substance which M. Braconnot called *leucine*. Leucine floats on water; it melts and in part sublimes and forms crystals. Nitric acid generates with it a peculiar acid, called the nitro-leucic, which forms salts.‡

2. *Boiling muriatic acid decomposes and dissolves fibrin*, producing a red or violet color; the diluted acid gives some nitrogen and a compound, which when neutral, is soluble in hot water, but it is less soluble, the more the acid prevails.

3. *Strong acetic acid, with heat, converts it into a tremulous jelly*, soluble in warm water, which evolves nitrogen, and if evaporated, leaves a transparent mass, insoluble without the addition of more acid.

4. *Nitric acid, sp. gr. 1.20 or 1.25, evolves pure nitrogen.*§ *By long digestion with this acid, fibrin approximates to albumen*;|| this change is speedily produced by boiling nitric acid, which forms oxalic acid and oxalate of lime, by means of the carbonate of lime in the muscle.¶ *Nitric acid, in these operations, converts a part of the muscle into adipocire.* (See oils and fat.)

* Five hundred grains of gelatin of isinglass gave, in close vessels, 56 residue, of which 54.5 were carbon and 1.5 phosphate of soda, with a trace of phosphate of lime. Five hundred grains of dry albumen gave 63.25 carbon, which, when burned, left 11.25 residuum, chiefly soda, rendered caustic by heat, with phosphate of soda and a trace of phosphate of lime. Five hundred grains of dry prepared muscle of beef gave 82.4 carbon, leaving 25.6 residue, chiefly carbonate of lime, mixed with a little pure lime and some phosphate.—Aikins' Dict. Vol. I, p. 435.

† See the sequel of this section.

‡ Braconnot, Ann. de Ch. et de Ph. Vol. xlii, p. 113.

§ Vol. I, p. 193, (b.)

|| The albuminous part was dissolved in the acid, and the part which was not dissolved was soluble in water and exhibited the properties of gelatin. The yellow acid, as it was called, appears to be a modified fibrin, with some nitric and malic acids.

¶ For several curious circumstances see Aikins' Dict. Vol. I, p. 435, and Thomson, Vol. iv, article Fibrin.

(f.) *Concentrated boiling alkalis dissolve fibrin*, and form a solution which is not a soap; it is decomposed by acids, but the precipitated substance is no longer soluble in acetic acid.

(g.) *Alcohol, sp. gr. .810, converts fibrin into a fatty matter*, soluble in alcohol and ether, and precipitable by water.

(h.) *Composition*, according to Gay-Lussac and Thénard.

Carbon,	-	-	-	-	53.360
Oxygen,	-	-	-	-	19.685
Hydrogen,	-	-	-	-	7.021
Azote or nitrogen,	-	-	-	-	19.934

100.

The equivalents nearest to the result of the analysis are carbon, 18 = 108, oxygen, 5 = 40, hydrogen, 14, nitrogen, 3 = 42, = 204, giving 1 equiv. more of carbon, hydrogen and nitrogen, and 1 less of oxygen, than there are in albumen.—H.

Miscellaneous.

(a.) *Dead muscle*, especially of young animals, is *very putrescent*.

(b.) *Dried muscular flesh is very enduring*. The jerked meat of savage nations is muscle, slightly salted and dried in the smoke. Running water and interment, under particular circumstances, convert muscle into a substance like spermaceti, and called *adipocire*.*

(c.) *Gelatin, albumen and fibrin, are the most important principles of animal matter*; although they appear convertible into one another, they are clearly distinguished by the action of water upon them.

Gelatin is soluble in water; gelatinizes if concentrated and cooled, and is again soluble.

Albumen is soluble in water, but coagulates at 160° or 170°, and the coagulum is not again soluble in water.

Fibrin is insoluble in water, under every circumstance.† Still, fibrin is found in solution in the blood, along with much albumen.

OSMAZOME.

This extract naturally finds a place immediately after fibrin, from which it is obtained; it is not however certain that it is a distinct principle.

Small pieces of muscle are softened, for an hour or two, in two or three times their volume of cold water, which is renewed several

* See this article in Aikins' Dictionary, and in Thomson's Chemistry, Vol. iv, under Putrefaction.

† Except that long continued boiling dissolves a little.

times, and the different waters are evaporated; the albumen coagulates by degrees and is removed; the colored syrupy liquor being treated with strong cold alcohol, leaves muriates of soda and potassa, and dissolves the extractive matter which is called osmazome; it is yellowish brown; does not gelatinize; taste and odor like those of beef soup, which is the better the more it contains of this extract; it usually exists in good soup, in the proportion of $\frac{1}{4}$. It is but little prone to putrefy. By mixing osmazome with a hot solution of gelatin, soup is made; tablets of it may be prepared for long voyages.*

BLOOD.

The most important principles of this fluid having been already mentioned, we will add, in this connexion, the other facts that are most interesting.

Blood has a peculiar smell, a slightly saline taste, and is a little heavier than water.†

1. *Coloring matter.*‡—The color resides in the external coatings of the red globules, (elliptical in birds and globular in the mammalia,) which, by a magnifier, may be seen floating in the fluid; their diameter is from $\frac{1}{1000}$ to $\frac{1}{500}$ of an inch; they consist of two substances, the one colorless, insoluble and floating on water, and the other matter, producing a red color by solution in water. We have no space to recite the progress of research and opinion. The color, obtained separate, by removing the fibrin and dissolving in water the red matter that falls through the serum, can be fixed as a dye in woollen cloth, imbued with nitrate or muriate of mercury; it appears, however, not to be a mere animal matter, as Mr. Brande supposed.§ Iron is now proved, by Dr. Engelhart|| of Gottingen, to exist in the red globules alone, and not in the fibrin or serum, freed from coloring matter; chlorine, passed through its aqueous solution, renders the iron sensible to the usual tests; its proportion is about $\frac{1}{1000}$ of the coloring matter; in some way or another, iron is probably the efficient cause of the color of blood, and as the sulpho-cyanic acid, has been proved to exist in the saliva, it is suggested that it may exist also in blood and be active in producing the color, as it gives a red tint with the per-oxide of iron; but of this, nothing certain is known.

2. *The crassamentum or clot*, coagulates in a few minutes after blood is drawn, and contains the fibrin, which exists naturally in solution in the blood, as is said in the form of white globules; the principal office of the fibrous part of the blood is evidently to recruit the waste of

* Thénard. Laugier.

† As may be observed when it drops into that fluid.

‡ Berzelius, Ann. de Ch. et de Ph. Vol. v. p. 42.

§ Phil. Trans. 1812. Ann. de Ch. et de Ph. Vol. i, p. 9. Id. Vol. xxxiv, p. 268, Vauquelin.

|| Edin. Phil. Jour. October, 1826, Jameson.

the muscles; the cause of the coagulation is unknown; when it happens, there is a rise of heat of 5 or 6 degrees.*—*Dr. Gordon.*

3. *The serum.*—Somewhat unctuous, and slightly alkaline, on account of a little free soda. Its composition appears to be water 905, albumen, 80, muriates of potassa and soda, 6, lactate of soda and animal matter, 4, = 10, soda and its phosphate, and a little animal matter, 4.1, loss, 0.9 = 1000. Berzelius; and Dr. Marcet, very nearly the same.

Carbonic acid has been stated to exist in blood, but there appears no decisive experiment to support this opinion. Serum coagulates by all the agents that produce that effect upon albumen; a fluid which oozes from the compressed coagulum has been called the serosity, but it seems to contain the principles of albumen, with perhaps a peculiar matter, differing from both albumen and gelatin.

4. *Respiration.*—The most important facts have been briefly stated in pages 199 and 373 of the first volume.

The capacity of the lungs of a man of common size, is estimated at about 290 cubic inches, out of which 160 or 170 cubic inches of air may be forcibly expelled,† leaving 120 or 130 in the lungs; in natural breathing, from 16 to 20 cubic inches are taken in at every inspiration; for each minute, 26.6 of oxygen gas are inspired, and in the calm breathing of a healthy man of common stature, about the same volume of carbonic acid is emitted; in twenty four hours, about 666 cubic feet are respired.‡

There is reason to believe, that the amount of carbon, (11 oz. troy per day,) formerly stated, on the authority of Allen and Pepys, p. 373, of Vol. I, to be withdrawn, is beyond the truth, as it exceeds the carbon in our food. There is no doubt however of the fact, that the blood is, by respiration, decarbonized to a great extent, and that this is one of the most important objects of that function. Still it does not follow, that this is all that happens in the arterialization of the blood; the removal of carbon, and the (perhaps) consequent acquisition of a florid hue,§ is evidently, a prominent thing.||

* This fact will aid much in understanding the evolution of heat in the circulation of the blood, as all the solid as well as fluid parts are drawn from it, and in becoming solid, they must emit the latent heat. Dr. Davy thinks, however, that the rise in the coagulation is overrated.

† By first inflating the lungs and then, (if we would measure the capacity,) by blowing through a wide tube into an air jar full of water.

‡ H. and Phil. Trans. 1808.

§ See Dr. L. C. Beck's deductions tending to shew that cyanide of iron may be formed in the blood by absorption of nitrogen, Am. Jour. Vol. xviii, p. 52; also the speculations of Prof. Vanuxem, as to the absorption of the nitrogen of the air, particularly by the earlier animals. Id. Vol. xii, p. 84.

|| But there may be other changes of which we are ignorant, and we are certain, that during the circulation, there are such changes as are connected with the ac-

As the combination of carbon to form carbonic acid, takes place both on the surface of the skin, and of blood drawn from the body, and in blood circulating in consequence of respiration artificially sustained in dead animals, this appears to be a chemical fact, independent of vitality.

It is not certain, whether in natural respiration, the carbonic acid is formed in the lungs, by excretion of the carbon or by the penetration of the oxygen through the membranes; or whether the oxygen is absorbed and finds the carbon in the course of the circulation, or being absorbed, expels or takes the place of carbonic acid already formed in the blood.

It is sufficiently established, that gases can penetrate membranes and even caoutchouc.* See p. 431.

Small animals as frogs and snails, sometimes furnish carbonic acid in greater volume than that of their own bodies, to an atmosphere of hydrogen in which they are confined, which implies that the carbonic acid was formed in their bodies. It would appear, from the most recent and best experiments, that nitrogen is both absorbed and expelled in respiration, but the amount of both results varies so much with the seasons and circumstances, that we cannot say as yet whether it is permanently received into the system through the lungs or not. A Guinea pig, confined in an atmosphere of oxygen gas, furnished more nitrogen than the bulk of his body, and the same result was obtained in an artificial atmosphere, in which hydrogen was substituted for nitrogen; in the latter case some hydrogen was absorbed, while nitrogen seems to have been exhaled. It appears that frogs, serpents and lizards, by means of their skins, affect the air in the same manner as they do with their lungs, and that in this way they can live long under water. Aqueous vapor is constantly emitted from the lungs; it is probably an exhalation from the surfaces, but it cannot be proved that it is not formed by the oxygen of the air and the hydrogen of the blood. The quantity in the human subject is supposed to be about 3 grs. in a minute.

5. *Animal heat.*—It results from the laws of life, that living animals can preserve a temperature nearly uniform, while inanimate bodies acquire that of the medium in which they are plunged. In addition to what has already been stated in Vol. I, p. 373, we may observe, that animal heat may be derived from several sources.

(a.) *From the formation of carbonic acid*, which, as it is, in all other circumstances, attended by evolution of heat, is doubtless pro-

quisition of chyle from the effects of digestion, and with the absorption and withdrawal of all that is secreted and appropriated for the nourishment of parts, or withdrawn, and rejected as excretions.

* The interesting experiments of Dr. J. K. Mitchell of Phil., prove, that living as well as dead membrane, is permeable to gases — *Phil. Med. Jour.* Nov. 1880.

ductive of the same result in this. Even if there is no difference in the capacity of arterial and venous blood for heat, if the oxygen is, agreeably to the experiments of Dr. Edwards, absorbed into the blood, it will find the carbon and evolve the heat over the whole body. So important, extensive and unremitting an agency as the formation of carbonic acid must in all probability contribute to the production of animal heat.*

(b.) *From secretion*, which, as already remarked, must evolve heat, because so many solid products are constantly drawn from the blood, and in ceasing to be fluid they must of necessity liberate caloric; and as these processes are going on, in every part of the body, the heat will be evolved over the whole system. That secretion is concerned in the production of animal heat is rendered highly probable by the fact that more heat is evolved by a living animal than would be generated by the combustion of the carbon in the carbonic acid which it forms.†

(c.) *By the nervous influence*.—Although we do not understand the nature of this power or its mode of operating, we cannot doubt that it is, in some way, efficient, either by an original energy of its own or by giving efficiency and peculiar character to other vital operations,‡ and the production of heat may be one of them. Animals, carefully decapitated, without great hemorrhage, or killed in some other way, and made to breathe artificially, have been found not only to form carbonic acid but the change of color of the blood continues to go on, while, as Mr. Brodie thought, their animal heat declined faster than if they had not been made to respire and their blood to circulate, but had been left to themselves. Others have found that the heat was, to a degree, sustained by the artificial respiration; but whichever result may be true, it does not justify the conclusion that the nerves are the sole cause of animal heat; for it is easy to understand, that animals decapitated or in any other way killed, and made to breathe artificially, cannot be in any condition to be compared with living animals, breathing naturally, and enjoying an undisturbed circulation of the blood. It is observed that animals require a supply of oxygen, in proportion to the size of their bodies and the vigor of their frames; more oxygen is consumed in a state of labor and activity than in rest; fishes and cold blooded animals find enough dissolved in water, but whales and other fishes that

* The soundness of this inference, at least as to its extent, must depend greatly upon the relative capacities of oxygen, and carbonic acid gas for heat; even the experiments of De la Roche and Berard give the greatest capacity to oxygen, although with a difference vastly less than was stated by Crawford.

† Ann. de. Chim. et de Phys. 1826.

‡ I refer the reader to the larger works on chemistry for the details of fact and opinion. Dr. Turner has given a very judicious view of the subject. I have not seen the work of M. Edwards, "*De l'Influence des agens Physiques sur la vie.*" It appears to abound with interesting observations. I have endeavored in the text to present only general conclusions, as to which there is little or no disagreement. See Phil. Trans. 1811, 12 and 14. Ann. de Ch. et de Ph. xxvi. The work of Mr. Ellis, on Respiration, is one of singular interest.

breathe with lungs come to the surface, and birds have their lungs ramified almost through every part of their bodies.

6. *Odorous principle*; discovered by M. Barruel. Obtained by putting a few drops of blood or of its *serosity*,* into a glass, and adding one third or one half as much strong sulphuric acid as blood, stirring the whole with a tube; the volatile odor will immediately be manifested. In this way the peculiar smell of the sweat or pulmonary exhalation of the animal will be perceived, so that not only the species, but sometimes the sex, can be distinguished.

The discoverer has applied this test to stains on linen, and after fifteen days or more, has found reason to confide in the discrimination, but in all cases, the trial should be made as early as possible. The spotted linen is cut, soaked in water for a few minutes, in a watch glass; sulphuric acid is then added, and it is stirred and the odor is observed.†

SEC. IV.—UREA,‡ OR URÉE.

Remark.—The name Urea has been given to the peculiar principle of urine, which is a very complicated fluid, whose usual composition will be stated at the end of this section, and which, in consequence of containing this substance, differs from a mere watery solution of salts and acids, &c.

I. PROCESS.

(a.) *By a gentle heat*, as of a water bath, carefully *evaporate* to a syrupy consistence, several quarts of fresh human urine secreted some hours after a meal; *to the residuum add*, at intervals, four times its weight of *alcohol*; most of it will dissolve with a gentle heat; the solution containing the urea, *will crystallize by evaporation and cooling*; the residuum consists of salts, chiefly phosphates and muriates.

(b.) Thénard's process. *To the residuum of the first evaporation, add an equal volume of nitric acid*, of sp. gr. 1.20; stir and chill it with a bath of iced water to harden the crystals of nitrate of urea; wash in ice water; drain and press in blotting paper; redissolve in water; *add carbonate of potassa or soda*, enough to saturate the nitric acid and gently *evaporate* almost to dryness; very good *alcohol* now *dissolves the urea, and gives it up by evaporation and cooling*.

(c.) Proust's; beginning by separating the nitrate of potassa by crystallization, *the residuary aqueous solution of impure urea is made into a thin paste, with animal charcoal*, and allowed to remain some hours; *out of this, cold water dissolves the colorless urea, and from the same fluid, carefully concentrated, pure alcohol, by boiling, re-*

* It is not said whether this is serum, or what is pressed out from coagulated serum, and has been called the serosity.

† English Quart. Jour. July to September, 1829, and Am. Jour. Vol. xviii, p. 148.

‡ Rouelle, in 1778, first noticed the peculiarities of the inspissated urine, and called it saponaceous extract of urine. Urea is peculiar to urine, and exists in that of all animals.

*moves the urea and, by evaporation and cooling, gives it in crystals; if not colorless, they may be redissolved and crystallized anew.**

II. PROPERTIES.

(a.) *Crystals, prisms of four sides, transparent, colorless,† pearly.*
 (b.) *Cool to the tongue like nitre; odor faint and peculiar; does not change the test colors; slightly deliquescent.*

(c.) *Sp. gr. 1.35; by a high heat, partly decomposed and partly sublimed, unchanged, but with an insufferable odor; by distillation in a retort, it gives about two thirds of its weight of carbonate of ammonia and one fourth of benzoic acid, besides carburetted hydrogen gas and a solid residuum of charcoal and of the muriates of soda and ammonia; there is also some prussic acid and oil.*

(d.) *Soluble at 60°, in less than two parts of water, and without limit in boiling water; dissolves in 5 parts of cold alcohol, and in less than one part of boiling. Not soluble in ether or oil of turpentine.*

(e.) *Nitric and oxalic acids, added to a concentrated aqueous solution, precipitate copiously, bright pearl colored crystals, but the acids are not neutralized.*

Composition of the nitrate—acid 47.37, + urea 52.63, or acid 1 equiv. 54 + 1 equiv. of urea 60=114. Sometimes, in disease, the urine contains so much urea, that a drop of nitric acid, placed beneath it in a watch glass, will produce crystals, and the proportion is inversely as the time required for the crystallization.‡

Nitric acid acts violently upon solid urea, especially if heated; much nitrous and other gas is evolved, with prussic acid and ammonia, and the dried residuum detonates like nitrate of ammonia.

(f.) *Although the accounts formerly given of the properties of urea, failed in precision, because it had not been obtained pure, it is worth remembering that the concentrated alcoholic solution of impure urea, with nitric acid, gives promptly the bright pearly crystals, like those of boracic acid, only tinged by coloring matter.*

(g.) *Neither infusion of nut galls nor of tan produces any precipitate in solution of urea, only a slight brown tinge.*

(h.) *The aqueous solution of urea putrefies, but much more rapidly if a little gelatine be added.*

(i.) *The ammonia of urine is derived chiefly from the urea; an equal quantity of the alkali is obtained by the manufacturers, whether it has undergone putrefaction or not.*

* The salts, left after the removal of all that is soluble in alcohol, were anciently called microcosmic salts; they are chiefly phosphate of soda and phosphate of ammonia.

† A yellow color was formerly considered as characteristic of urea, and the color of urine was attributed to it; but this mistake is now corrected, and the color is now attributed to animal matter, not yet, I believe, isolated.

‡ Which may be from a few minutes to two or three hours; in healthy urine, it may take half an hour.

(j.) *Diluted sulphuric acid 1 part and urea 4 parts, produce, without effervescence, an oil, which concretes by cooling, and acetic acid, ammonia and sulphate of ammonia, are the ultimate results.*

(k.) *Muriatic acid dissolves urea, without altering it; chlorine gas is largely absorbed by solution of urea, and carbonate and muriated ammonia are formed.*

(l.) *Alkaline solutions dissolve urea, with evolution of ammonia and of its carbonate, arising from the decomposition of other ammoniacal salts and partly of the urea itself.*

(m.) *Urea tends to change the forms of some crystals; thus, muriate of soda, in a solution of urea, crystallizes in octahedrons instead of cubes, and muriate of ammonia in cubes instead of prisms.*

(n.) *Urea, both spontaneously and by the action of reagents, undergoes decomposition more readily than any other animal principle.*

(o.) *Composition.**

Oxygen,	-	-	-	26.66=1 equiv. or $\frac{1}{2}$ vol.,	8
Nitrogen,	-	-	-	46.66=1 "	1 " 14
Carbon,	-	-	-	19.99=1 "	1 " 6
Hydrogen,	-	-	-	6.66=2 "	2 " 2
Loss,	-	-	-	.03	

100.

30

Urea differs from all other animal substances, in the abundance of nitrogen it contains; it is not however as usually stated, decomposed by the heat of boiling water; on the contrary, a strong aqueous solution can be boiled a long time without evolving carbonate of ammonia, but, when the water is evaporated, the urea itself melts at 248° F., boils and then suffers decomposition.†

Remark.—The surprising coincidence between the composition of urea and of cyanate of ammonia, discovered by Wöhler, will be mentioned again under the prussic compounds.

URINE.

In connexion with urea, it will be proper to mention the other principles contained in the fluid which affords it. *This fluid, being entirely excrementitious, and destined to remove from the system superfluous or injurious substances, is exceedingly various in its composition as well as in its quantity; the latter is usually estimated, on an average, at from 30 to 40 ounces per day, perhaps about 2 lbs. Urine of the morning, from a person who has fed heartily before sleeping and taken no more fluid than was indispensable, is regarded as the best sample of the healthy fluid.*

Urine usually reddens litmus, and this has been attributed to a free acid; probably it is rather a bi-salt, perhaps super-phosphate of lime

* Prout, cited by Henry.

† Eng. Quar. Jour. No. 14, p. 427.

and super-urate of ammonia; *urine becomes alkaline by spontaneous decomposition*, and also by boiling, carbonate of ammonia being generated. Ammonia and lime water* precipitate phosphate of lime, containing some magnesia.† Oxalic acid precipitates lime. The cloudy deposit from urine is often mucus, but it is partly super-urate of ammonia, which is less soluble in cold than in hot water; it used to be said that uric acid spontaneously precipitates, and it will do so if, to recent urine, muriatic acid be added, which, according to Dr. Prout, decomposes the super-urate.

Benzoic acid, existing in the urine of infants,‡ is precipitated along with the uric acid, by muriatic acid, but alcohol dissolves the benzoic acid, and thus they are separated.

Acetate of lead decomposes the soluble phosphate of lime and precipitates phosphate of lead. Nitrates of silver and of lead, precipitate the muriatic and phosphoric acids. Muriate of baryta does the same, and also precipitates the sulphuric acid, if present; if the muriate of baryta has an excess of acid, it will dissolve the phosphates and precipitate only the sulphates. All the alkalies and alkaline earths, and their soluble salts, produce precipitates by decomposing the phosphates. The specific gravity of urine, as stated by Dr. B. Robinson and admitted by Dr. Henry, is 1030, pure water being 1000.

The composition of urine has been differently stated by different chemists. The most recent table is given by Dr. Turner, on the authority of Prof. Berzelius. In 1000 parts of urine, there are,

Water, - - - - -	932.
Urea, - - - - -	30.10
Uric acid, - - - - -	1.
Free lactic (acetic) acid, lactate of ammonia and inseparable animal matter, - - - - -	17.14
Mucus, - - - - -	.32
Sulphate of potassa, - - - - -	3.71
Sulphate of soda, - - - - -	3.16
Phosphate of soda, - - - - -	2.94
Phosphate of ammonia, - - - - -	1.65
Muriate of soda, - - - - -	4.45
Muriate of ammonia, - - - - -	1.50
Earthy phosphates, with a trace of fluuate of lime, - - -	1.
Siliceous earth, - - - - -	.03

* The precipitate by lime water, when heated with sulphuric acid, afforded to Berzelius, vapors which corroded glass, thus indicating fluoric acid.—Thomson's Ann. Vol. II, p. 416.

† There is .11 more of magnesia than exists in the earth of bones or in the ashes of blood.

‡ Berzelius could not find it in the urine of infants.

The presence of sulphur* is inferred from the blackening of silver by evaporating urine in a silver vessel. Dr. Henry adds to the articles in the above list, free phosphoric acid, fluoric acid, benzoic acid, † phosphate of lime, ‡ phosphate of magnesia, gelatine and albumen. The two latter appear to be present in very small quantity, except in disease. § After twenty four hours, the uric acid, urate of ammonia and phosphate of lime, are in a good degree deposited; the uric acid is destroyed by ignition and leaves the phosphate, or the latter is dissolved by dilute nitric acid and leaves the uric acid, which is much increased by adding to the urine almost any acid and allowing it to stand a few days. If the phosphates are first decomposed by nitrate of baryta, then the muriates are precipitated by nitrate of silver.

It is not my intention to enter into the phenomena produced in urine by disease; this is the more appropriate business of the medical man. It may be added, however, that in a state of disease, oxalic and nitric acids are produced by the kidneys, in addition to the other acids, the sulphuric, the phosphoric and the uric, which they are supposed to generate, when their functions are healthy, and the oxalic acid, uniting with lime, forms one of the worst kinds of calculi. Albumen is, in certain dropsical affections, so abundant as to produce spontaneous coagulation, sometimes even in the bladder.

Some other facts may be mentioned in connexion with the notice of calculi and of the animal acids. ¶

SEC. V.—ANIMAL SUGAR.

Remarks.—Saccharine substances are rare in animals, and no variety of animal sugar has been found, perfectly analogous to that of vegetables. There are but two kinds of sugar, that are unquestionably of animal origin.

* Dr. Prout supposes that he has observed phosphuretted hydrogen in decomposing urine, and thence infers the presence of phosphorus.

† Dr. Turner doubts the existence of any free acid in urine, and Dr. Prout imputes the acid reaction to super salts. (See p. 570-71.)

‡ I have never known urine to fail giving a precipitate with ammonia or lime water; it must be an earthy salt and has usually been supposed to be owing, at least in part, to super-phosphate of lime, which is most abundant when lime water is used, because it is there formed as well as precipitated.

§ Carbonic acid has been supposed to exist in urine and the froth has been attributed to it, but it probably arose from decomposition.

¶ I refer the student, for additional views, to the Elements of Dr. Henry and Dr. Turner, and the original authorities cited by them and others are, Ann. de Chim. xxxi. 48, xxxvi. 248, lxi. 311, lxi. 256, lxxxii. 189, xciii. 271, Phil. Mag. ii. 249, xxiii. 298, Thomson's Ann. ii. 416, Dr. Prout on Calculus, &c. Dr. Marcet on do.

1. SUGAR OF MILK.

I. PROCESS.

(a.) Milk having been coagulated by rennet, *the whey is evaporated* to the consistence of syrup, and when cool it *deposits a sweetish mass.**

(b.) *It is redissolved* in water, clarified with white of egg, and *again evaporated* to a syrupy consistence, when, *on cooling, it deposits brilliant white crystals*, of sugar of milk.

II. PROPERTIES.

(a.) The crystals are *parallelopipeds*, terminated by four sided pyramids.

(b.) *Taste, sweetish, but peculiar*; soluble in 7 parts of cold and about 4 of boiling water; insoluble in alcohol; thus it differs from vegetable sugar.

(c.) *When heated and inflamed, it smells like burning sugar*; leaves about $\frac{3}{8}$ of its weight of muriate and carbonate of potassa, and yields an empyreumatic oil, having the odor of benzoic acid.

(d.) *Nitric acid converts it into the saccho-lactic acid*, which see.†

(e.) *Composition*, according to Gay-Lussac and Thénard, oxygen 53.834 + carbon 38.825 + hydrogen 7.341 = 100. Dr. Prout gives 40 carbon + 60 water, or its elements, as the composition of sugar of milk, and he agrees very nearly with Berzelius.† Sugar of milk does not undergo the vinous fermentation, and when milk ferments, its sugar appears not to be the agent, because as much sugar is found in it, after fermentation, as before. Sugar of milk contains no nitrogen; it can, by the agency of sulphuric acid, be converted into real sugar; it must be boiled in it, in a state of dilution. See Johnson's Animal Chemistry, for additional facts.

2. DIABETIC SUGAR.

Remark.—In the disease called diabetes mellitus, sugar takes the place of urea.

PREPARATION AND PROPERTIES.

(a.) From 1½ lb. of diabetic urine, Prof. J. R. Coxe, of Philadelphia, obtained 2½ oz. of solid saccharine matter; the diabetic urine readily fermented and alcohol was obtained by distillation; by the action of the nitric acid, this sugar afforded also oxalic acid.

(b.) *By exposing the solution to the air*, and removing the scum which forms, *Dr. Henry obtained white crystals*, as beautiful as those from vegetable sugar. Dr. Wollaston also prepared it in white grains like vegetable sugar.

* It is prepared pretty largely in some of the cantons of Switzerland, and is used for culinary and medicinal purposes. In that country they pour the evaporated whey into earthen pots, and allow it to solidify and dry in the sun.—*Aikins*.

† Some oxalic acid is produced at the same time.

† Phil. Trans. 1827.

(c.) When thoroughly purified, therefore, *this sugar appears not to differ at all from vegetable sugar*, but its formation in the animal economy is very singular, and hitherto not explained.

*Chevreul** states, that by concentrating diabetic urine and leaving it to itself, he obtained sugar in crystals; having drained, pressed, and dissolved them in boiling alcohol, and exposed them to spontaneous evaporation, he *obtained the crystals perfectly white, and having all the properties of the sugar of raisins*, that is, the same crystallization, solubility in alcohol and in water, and the property of melting with a gentle heat.

Remark.—Honey is mentioned, by some writers, as a variety of animal sugar; as we are without decisive evidence as to the degree in which it is modified by an animal process, we leave it where it has been already mentioned, under vegetable sugar, Vol. ii, p. 424.

SEC. VI.—ANIMAL RESINS.

Remark.—There is nothing in the animal kingdom precisely analogous to vegetable resin; but several respectable authors have agreed to arrange the following substances under the head of animal resins.

1. Castor; 2. Cerumen or ear wax; 3. A peculiar substance in bile.

1. *Castor.*—*Obtained from the larger of two small sacks in the inguinal region of the beaver.* Color yellow, almost fluid when recently taken from the animal; by exposure, hardens, grows darker, and exhibits a resinous appearance; taste, bitter and acrid; odor strong and aromatic.

Composition, according to *Bouillon LaGrange*—1. Carbonate of potassa; 2. carbonate of lime; 3. carbonate of ammonia; 4. iron; 5. resin; 6. mucilaginous extract; 7. volatile oil on which its odor depends. Castor is regarded as a powerful antispasmodic.

2. *Cerumen or ear wax.*†—*Taste bitter, easily melts and emits an odor slightly aromatic;* burns readily like an animal oil, emitting an ammoniacal odor and leaving a little charcoal.

Alcohol dissolves $\frac{1}{2}$ of it, and the residuum is albumen mixed with oil and soda, and phosphate of lime is obtained by incineration. The alcohol, on being evaporated, leaves a bitter orange colored matter resembling the resin of bile. It is soluble also in ether.

* Ann. de Chim. Vol. xcv, p. 321, in a note.

† Dr. Torrey informs me that there is a paper on cerumen, in one of the volumes of Medical Observations and Inquiries, by a society of physicians in London, published fifty or sixty years ago, in which the writer proves that ear wax is not a resinous substance at all, but is more soluble in warm water than in any other menstruum—a matter, (as Prof. T. justly observes,) of some practical importance in the treatment of certain kinds of deafness; the original paper is not within my reach.

3. *Resin of bile*—obtained from the recent bile of the ox, 32 parts with 1 of strong muriatic acid; a coagulum of mucus and albumen, that falls after some hours, is separated by straining, and from the green fluid, a green precipitate is obtained, by gentle evaporation, which, after being separated and washed, affords the substance that has been called resin* of bile. Color, dark brown; spread thin on a white ground, it appears grass green; very bitter; fusible and combustible; soluble in both cold and hot water, still more so in alcohol, and precipitated by water. With pure alkalies, forms saponaceous compounds, and is precipitated by acids.—H.

BILE.

It is particularly difficult to present an intelligible account of this complex fluid, especially as those who have analyzed it have not always been agreed in their results, and the research may be considered as still unfinished.

Sp. gr. 1.26; secreted, as is supposed, from venous blood, and accordingly in its composition, carbon and hydrogen prevail; its office is to aid digestion; it is miscible with water in every proportion; it contains about $\frac{1}{4}$ of free soda, but its color prevents it from giving the usual indications with tests.†

In the bulky charcoal, that remains from the evaporation and incineration of bile, there are found muriate, phosphate and sulphate of soda and lime, and traces of oxide of iron.

Immediate constitution.

By the analysis of Thénard,‡ the bile of the ox consists of a yellow coloring matter, a resin and picromel, a principle having, (as its name indicates,) a taste both bitter and sweet. According to Thénard, 800 parts of ox bile consist of water 700, resin 15, picromel 69. yellow matter 4, soda 4, phosphate of soda 2, muriate 3.5, sulphate 0.8, phosphate of lime 1.2, and a trace of oxide of iron. He attributed the solubility of the resin, to the joint action of the picromel and soda; for the process by which picromel was obtained, I refer to Thénard's Chem. Vol. iv, already cited.

It is insoluble in water and in alcohol, and does not crystallize, and renders the resin soluble in water. It gives bile its peculiar odor.§

* Its resinous character is denied by Berzelius.

† Murray says it turns violets green.

‡ Mémoires d'Arcueil.

§ Picromel, as obtained by Tiedman and Gmelin, is in opaque rounded crystalline particles, soluble in water and in alcohol, but insoluble in ether; its taste is sweet without bitterness, but it contains nitrogen, and is not a variety of sugar; it aids in dissolving the resin of bile, and the solution has a bitter and sweet taste, which is the peculiar taste of bile.—T.

The yellow matter is peculiar to bile, renders it putrescent, and forms biliary concretions; it is insoluble, but is rendered soluble by soda, resin, and picromel.

Prof. Berzelius differs from Thénard; he denies that there is any resin in bile, and groups the yellow matter, the resin and the picromel of Thénard under the name of biliary matter; he states that the coloring matter can be thrown down by an acid, &c.

According to him, bile in the 1000 parts, is composed of water 907.4, biliary matter 80, mucus 4, alkalies and salts 9.6.

A more recent examination by Profs. Tiedman and Gmelin, re-establishes the picromel and resin of Thénard, but ascribes rather different properties to the latter when purified.* They find the bile however very complex, to contain in 100 parts, 91.5 of water, and besides those principles just named, they find cholesterine, osmazome, mucus, asparagin, and many salts, chiefly of soda, but none of the latter free.† The subject is far from being in that state of maturity that would make it useful to pursue it farther in this work. Human bile is similar to that of the ox. Nine tenths or more of it are water; the yellow matter and resin, (in equal quantities,) form $\frac{1}{10}$, and the rest is soda, salts, and a little iron.—Thénard. Berzelius finds in 1000 parts of bile, 908.4 of water; 80 picromel; 3 albumen; 4.1 soda; 0.1 phosphate of lime; 3.4 common salt, and 1 phosphate of soda, with some phosphate of lime.

Seourers use bile‡ in cleaning woollen clothes, and often prefer it to soap; its detergent powers are owing to the soda and to the triple compound of soda, resin, and picromel; it removes grease spots, &c.

A color is also obtained from bile for the painters; the gall is sometimes mixed with other colors, as it unites with the oily matters of the paints. The yellow coloring matter of bile, when concentrated, forms a fine pigment; it is also found in biliary concretions.

SEC. VII.—ANIMAL OILS.‡

The principal varieties, under the name of fat, oil, lard, suet, butter, tallow, &c. are well known; one of the most obvious differences is in the relative degree of hardness, but this is a mere accident depending on temperature.

* See the note on page 575.

† See a fuller abstract in Henry, Vol. ii, and in Turner.

‡ When concentrated by evaporation, it keeps a good while; its alcoholic solution has been used in medicine.

§ Among the oils the animal oil of Dippel is usually mentioned; it is the product of the destructive distillation of horn and of different albuminous and gelatinous substances; it was made limpid by a redistillation, and had formerly some medical reputation, which it has long since lost.

1. **ANIMAL FAT** is generally extracted by heat with the addition of a little water to prevent scorching; the fat floats, and it is sometimes strained to separate membranes, and at other times it is allowed merely to congeal.

2. **TRAIN OIL.**—This is the common fish oil, extracted from the blubber of the whale, (chiefly the *Balæna Mysticetus*;) and other fish. It is purified by agitation with sulphuric acid, with the subsequent addition of water.* Chloride of lime can also be applied to this purpose.† It is used chiefly for affording light, either in lamps or in the form of gas.

Composition.

Carbon,	12 equiv. = 72	per cent carb.	68.87
Oxygen,	2 16	oxy.	16.10
Hydrogen,	17 17	hydrog.	15.03
	105		100.†

3. **SPERMACETI.**—Obtained from the cranium of the cachalot or *spermaceti whale*; but it is a different substance from the brain. It is pressed in a woollen bag; the spermaceti oil exudes; in winter, one part congeals while another part remains fluid, and from its being strained out in cold weather the latter is called winter strained oil.§ The solid spermaceti is melted, strained, and washed with a weak solution of potassa. It is softer and more brittle than white wax; it is soluble in hot alcohol, ether and oil of turpentine. It is a well known material for candles.

Composition of the oil.

Carbon,	10 equiv. = 60	per cent	78
Oxygen,	1 8		10.20
Hydrogen,	9 9		11.80
	77		100.||

Spermaceti forms a soap with potassa; when it is decomposed by an acid, a substance separates, to which Chevreul gave the name ethal, (from the first syllable of ether and alcohol;) it is white, fusible, and more soluble in alcohol than spermaceti.

STEARIN.—ELÄIN.

The suety part of animal matter has been separated from the oily by Chevreul and Braconnot,¶ who have distinguished them by the names STEARIN, *στέαρ*, suet, and ELÄIN, *ελαιον*, oil.

* Thomson.

† Edin. Jour. Vol. vii.

‡ Thomson.

§ It is much valued, since lamps fed by it will not go out, in very cold weather.

|| Dr. Ure.

¶ Ann. de Chim. Vols. 88, 93, 94, 95. Ann. de Ch. et de Ph. Vol. ii, and subseq. Vol. II.

Boiling alcohol, sp. gr. .791 to .798, *dissolves both*; the stearin is deposited by the cooling of the solution; it is in white needles and is purified by a second solution. The eläin is obtained by evaporating the alcohol to $\frac{1}{2}$ of its volume, and it is afterwards exposed, repeatedly, to severe cold, and that which remains is pure eläin.

By simple pressure and cold, Braconnot separated the two, using grey bibulous paper, which absorbed the eläin from the congealed oil, and gave it up again by pressure under water. The stearin remained untouched. Eläin, in a vacuum, evaporates without decomposition; by heat, it yields the acetic, sebacic, margaric and oleic acids, besides inflammable gases and oils. Eläin is very good for lubricating delicate machinery, as in watches, since it does not become rancid or readily congeal.*

A strong solution of caustic soda, agitated and gently heated with any oil, (unless one that is rancid or has been altered by heat,) forms a soap with the stearin and leaves the eläin, which is obtained by straining through a towel and decanting the remains of the alkaline solution.†

All fatty substances and all oils, vegetable as well as animal, contain these two principles. Even volatile oils contain a concrete substance, analogous to camphor. If upon 2 parts of the suet of pork 4 of strong sulphuric acid is first poured and then boiling water is added, the stearin and eläin will both be obtained. As the stearin prevails in fat it is more firm, and as the eläin prevails, it is more fluid.‡

ACIDS OF THE OILY AND FATTY BODIES, animal and vegetable, formed during saponification.

1. STEARIC ACID.—The stearin of the fat of pork, beef or mutton is altered in its constitution and becomes an acid, when soap is made with either of those varieties of fat and potassa. Other acids§ are formed, at the same time, as will be presently mentioned, and all of them form salts with the alkali.||

2. MARGARIC ACID.—Called at first by the name margarine, *μαργαρίνη*, in allusion to its lustre. A soap is formed by potassa and hogs' lard; water dissolves it in part, but the margarate of potassa is

* Oil of olives and oil of ben, are said to be the only oils fit for lubricating the machinery of time pieces, because they do not become rancid and thus act on the metals; but they become fixed by a moderate degree of cold; when the oil of olives is deprived of its stearin it then remains perfectly fluid at every temperature. I am informed that the oil of the porpoise is generally used.

† Ann. de Ch. et de Ph. Vol. xxii, p. 330.

‡ Braconnot found summer butter to contain in 100 parts, stearin, 40, eläin, 60; winter butter had stearin, 65, and eläin, 35. Hogs' lard had stearin, 33, eläin, 62; beef marrow, 76 and 24; mutton marrow, 26 and 74; goose fat, 32 and 68; olive oil, 28 and 72; almond oil, 24 and 76, &c.

§ For details, see Chevreul's various memoirs in the Ann. de Ch. and Ann. de Ch. et de Ph.: also, in his treatise upon the fatty bodies.

|| For the method of separating these salts and obtaining the stearic acid, see Turner's Chem. 8d Am. edition, p. 505.

not dissolved, and falls in heavy scales, which, being washed in water and recrystallized from alcohol, is decomposed by muriatic acid, and the margaric* acid floats. It is very soluble in hot alcohol, and on cooling, and also on congealing from fusion, crystallizes in pearly needles. It has been found, both free and combined, in the putrefied albumen of milk. Its composition is carbon, 79, hydrogen, 12, and oxygen, 9. There is a margarate and bi-margarate of potassa.

3. **OLEIC ACID.**—This acid is formed along with the margaric, in the soap made of potassa and hogs' lard. This oleate of potassa remains in solution in the water, and is decomposed by tartaric acid; the oleate is then formed anew, and decomposed, several times in succession, to obtain the acid pure. It may be obtained from a potassa soap, made with a fluid vegetable oil, as linseed. From the dried soap, cold alcohol, sp. gr. .821, dissolves the oleate and leaves the margarate of potassa behind; the aqueous solution of the oleate is decomposed by an acid, and the oleic acid appears as an oily fluid, colorless and inodorous, or only slightly rancid; insoluble in water, but very soluble in alcohol, and crystallizes at 35° F. Its composition, omitting water, is carbon, 80.94, hydrogen, 11.36, oxygen, 7.7.

4. **SEBACIC ACID.**—Obtained by distilling hogs' lard or suet, and removing the fat from the product, by melting it with hot water, which dissolves the sebacic acid with some acetic; the acetate of lead precipitates the sebacic acid, and the sebate of lead, being decomposed by sulphuric acid, the sebacic acid floats. It is soluble in boiling water, and still more so in alcohol; it has various acid properties, perhaps not worth detailing, as it is suspected by Berzelius to be only a modified benzoic acid.

Various other acids are produced, during saponification, even with vegetable oils, but they appear to possess no particular importance.

VARIETIES OF STEARIN OR OF ANALOGOUS SUBSTANCES.

1. **CETINE.**†—This is a name for the pure stearin of spermaceti; it is obtained by dissolving it in boiling alcohol, of which it requires about 13 parts; from the cooling solution, it falls in white crystalline scales. During its saponification with potassa, a peculiar acid is formed, to which Chevreul gave the name of the *cetic*.

2. **ADIPOCIRE**‡—from *adepts* and *cera*, *fat* and *wax*, as the substance has a resemblance to both.

The name was first given to the fatty matter, into which the human bodies, except the brain, were found, in a great measure, converted, on opening the graves in the cemetery of the Innocents in Paris, in

* By abbreviation, instead of margaritic.

† Ann. de Ch. et de Ph. Vol. vii, p. 155. Also, Ann. de Ch. Vol. xcv, p. 17.

‡ According to Chevreul and Gay-Lussac, the fatty matter is not formed, but developed; Ann. de Ch. et de Ph. Vol. iv, p. 71; for a fact produced by Dr. Thomson, in support of the contrary opinion, see Ann. Philos. Vol. xii, p. 41.

1782.* It is produced more promptly, by placing animal muscle in a perforated box, and submersing it for a few months in a running stream; or better by digesting the muscle in strong nitric acid, and removing the acid by the action of water.

Adipocire has lost much of its importance, since it is no longer regarded as a peculiar fatty principle, but rather as a soap of ammonia and margaric acid. The history of its first discovery in the Parisian graves, is however very interesting.

It is soluble in boiling alcohol and ether, from which it falls nearly white, the original yellow color being transferred to the alcohol.

3. CHOLESTERINE. (χολή, bile, and στερεος, solid.) This was mentioned under bile; it was formerly supposed to be analogous to spermaceti and to be a variety of adipocire, but it is now regarded as a distinct principle. It forms the basis of most of the biliary calculi. It is extracted, by boiling the powdered biliary calculus in alcohol; the solution is filtered while hot, and cholestérine crystallizes by cooling. It is tasteless, inodorous, and insoluble in water; greatly resembles spermaceti, but is less fusible and does not form a soap with alkalis. Composition, carbon 85.095, hydrogen 11.88, oxygen 3.025; it contains no nitrogen. By the action of an equal weight of strong nitric acid, it is converted into a peculiar acid, the cholesteric. As the fluid cools, the acid falls, of a yellow color, and more is obtained, by diluting the fluid with water. It is insoluble in water, but soluble in alcohol, especially if hot; from a fresh solution in hot alcohol, it falls in white needle crystals; it reddens litmus and forms cholesterates with the bases; it is decomposed, at a heat above 212° , and forms an oil.† Cholestérine has been found, (as already mentioned) in human bile,‡ and among other instances, in that of a person in health, suddenly killed; also in that of the inferior animals, as of the ox, dog, pig and bear.§ It is also found in tumors and abscesses, in parts of the body having no apparent connexion with the liver.||

4. AMBERGRIS.¶—A concretion, supposed to be formed in the stomach of the spermaceti whale,** (Physeter macrocephalus;) it is found, floating, near the coasts of India, Africa, and Brazil, in masses of 50 or 100 lbs.†† Sp. gr. .849 to .844; color, ash gray,

* See Fourcroy's original memoir in the Paris Journals, also Vols. ix and x, of his system, and the abstract in Aikins' and in Ure's Dictionary.

† Ann. de Chim. et de Phys. Vol. vi, p. 401, and Jour. de Phar. Vol. iii, p. 292.

‡ Ascertained by Chevreul, in that of nine persons.

§ Ann. de Chim. et de Phys. Vol. xxxi.

|| For several of these cases, see Dr. Turner's Chem. 3d Am. ed. p. 507.

¶ It is usually mentioned by authors as a resin, but appears to be more allied to the stearic substances.

** Believed to be a production of disease, because it has been taken from the intestines of sick or dead whales.

†† Edinb. Encyc.

with brownish yellow and white streaks; smell agreeable, and improves by keeping; taste insipid.

Composition, according to Bouillon LaGrange, 52.7 adipocire, 30.8 resin, 11.1 benzoic acid,* 5.4 carbon. Ambreine is obtained by digestion with hot alcohol; sp. gr. 0.827; on cooling, irregular, voluminous white crystals fall, fusible at 86° , and rising in a white smoke a little above 212° ; odor of the crystals agreeable, but it is lost by repeated solutions and crystallizations; it is tasteless and does not form a soap with alkalis. Nitric acid converts it into a peculiar acid called the ambreic; the ambreates appear to be unimportant.†

OTHER BODIES.

1. *Butyrine*.—A name given by M. Chevreul, to one of two oils obtained by melting butter; they are combined with stearin, and there is also some curd and whey, and butter is composed of them and the stearin and oils. Butyrine dissolves in cold alcohol; the other oil resembles eläin. When butter is saponified by potassa, and the soap is decomposed by tartaric acid, the water of the solution contains several acids, called the capric, caproic and butyric; they are volatile and give the peculiar odor to butter.‡

M. Chevreul has also mentioned *phenicin*, from the fat of the porpoise, (*Delphinus Phocæna*,) it is combined with eläin, and affords, after saponification and decomposition, an acid called the phocenic.

The fat of the goat and sheep affords a principle called hircine, and this, in the same manner affords an acid, *the hircic*, (*hircus*.)

2. *Glycerine*.—This was first obtained by Scheele; it is, as its name implies, saccharine; it was formerly called the sweet principle of oils, and is formed, or evolved, during the saponification of fat, and by the action of metallic oxides, as litharge. It may be formed with olive oil and litharge, equal parts; they are heated together; the lead is removed by a current of muriatic acid gas; we filter and evaporate and obtain a syrupy uncrystallizable liquid, which, according to Vogel, may be converted into sugar by sulphuric acid. It remains in the mother water, when potassa soap is made; the free alkali is removed by an acid, and the evaporated syrupy fluid is dissolved in alcohol, and again obtained, by evaporation, in the form of a sweet syrup, as above. It does not ferment, and when of the sp. gr. 1.27, is composed of carbon 40.071, hydrogen 8.925, and oxygen 51.004.

3. *Artificial fat*.—Carbonic acid gas 1 volume, carburetted hydrogen 2, and hydrogen 20, being passed, in mixture, through an ig-

* Others have failed to find benzoic acid.

† Ann. of Phil. Vol. xvi, p. 93.

‡ For numerous details respecting butter, see Ann. de Chim. et de Phys. Vol. xxii, p. 366.

nited porcelain tube, afforded small white crystals, which floated on water, dissolved in alcohol and became an oil by heat.* A mixture of coal gas and aqueous vapor afforded a similar compound.†

4. *Cerebral pulp*.—This might, with perhaps more propriety, have been mentioned under albumen, but as it contains oils, it may be allowed to fall into the train of the fatty bodies, not as a proximate principle, but as an appendage. Its composition is, in 100 parts, water 80, albumen 7, white fatty matter 4.53, red fatty matter 0.70, osmazome 1.12, phosphorus 1.5, acids, salts and sulphur 5.15.‡ The nerves and spinal marrow are similar to the brain.

On account of the albumen which it contains, the brain is partly soluble in water, and is coagulated by heat, acids, and various metallic salts. It is partly saponified by alkalies, and the oils and osmazome, with which the soap is formed, are soluble in alcohol; after evaporation, the osmazome is taken up by cold alcohol, and the oil remains. In the cemetery of the Innocents, the brain was not changed into adipocire, (see adipocire.)

SOAP.

In a work like the present, we can do little more than indicate the principles of the important chemical arts, omitting most of their details.§ Soap may be mentioned under either vegetable or animal oils, as it is made from both, but to avoid repetition, a more exact account of its composition has been reserved for this place.

Soap was known to the ancients;|| it is often named in the Old Testament; the English word is said to be from *sapo*, σαπων.

The soaps commonly known, are formed only between caustic alkalies and oils, vegetable or animal; the hard soaps are made with soda and the soft with potassa.

1. *Hard and soft soap.*¶

White soap, of olive oil and barilla; of the latter 500 lbs. are rendered caustic by boiling with 100 of lime, and the ley will saponify 600 lbs. of olive oil; it is concentrated by evaporation, and added, either all at once or by portions, heat being usually employed; it can however be made in the cold; the soap separates from the spent

* Berard, Thomson's Ann. Vol. xii, p. 41.

† Dobereiner.

‡ Ann. Phil. Vol. i, p. 332.

§ See Vol. I, p. 242. The important work of Chevreul, and another by Dumas, on Chemistry, applied to the arts, have recently arrived in this country, but I have not had opportunity to consult them.

|| Aikins.

¶ Different degrees of hardness in soaps are obtained by using potassa and soda, at the same time, in various proportions, and soaps are colored blue by indigo, yellow by turmeric, &c.

ley. Medicinal soap is made in the cold, with 2 parts of olive oil and 1 of caustic soda; they are a good while agitated together, and when they have acquired a certain degree of consistency the mass is cast in earthen moulds.

Soap of tallow is made in England, and largely in the U. States, and is the best in common use; when scented with oil of caraway seeds and cast in a mould, it is used for the toilette and called Windsor soap. Hogs' lard is also used for toilette soap.* Sometimes fish† oil is used for coarse soaps, as well as oil of nuts, linseed oil, &c.; rosin is often added to impart the yellow color and the odor.‡ Common salt improves soft soap, and even converts it into hard; 8 lbs. of potash soap of olive oil are, by boiling 2 hours with 6 lbs. of common salt, turned into 5 lbs. of hard soap; the great loss of weight is occasioned, chiefly, by the water of the soft soap.

Soft soaps are more acrid than the hard; the spent ley does not separate, but concretes with the proper soap. In making the domestic soap of this country, commonly a half bushel of lime is used for a hog-head of ashes; the ley bears an egg, and about 30 lbs. of animal fat (the remains of cooked meat§) are saponified by two pails full (about 6 or 8 gallons) of the ley, which is added by degrees and boiled. Cold soap is made by adding a similar ley to the melted grease, but it takes some days or weeks.

Marbled or veined soaps; to the soap just separated from the spent ley, new ley is added and then solution of sulphate of iron, whose oxide is thus precipitated black or dark green, and the red oxide of iron, (colcothar,) diffused in water, is stirred in, and by manual dexterity, it is mixed so as to produce the peculiar appearances.||

A soap of bees wax is made, which is employed chiefly in encaustic painting.

Properties of alkaline soaps.

Detergent, because the alkali is not entirely blunted by the combination; alkalies are more powerful without the oil, but they are too energetic; soda is however, much used in Great Britain.

Soluble or diffusible in water, without limit; a viscous solution, easily inflated.

Soluble in alcohol;¶ decomposed by acids which take the base; the alcoholic solution detects free acids and earthy salts in water.

* Other toilette soaps are made with butter, or with almond, nut or palm oil, &c.

† Its offensive smell causes it to be rejected, except for manufacturing purposes.

‡ Proportions, for a good yellow soap—tallow 25, oil 4½, rosin 7, barilla 18, residuum of waste ley, evaporated and calcined, 10, and palm oil ¼ a part.

§ Of the nature of tallow or suet, but they use also rancid butter, hogs' lard, &c.

|| For other particulars and varieties of the process in forming this soap, see Gay-Lussac's Cours, Vol. II, Leçon 29, p. 6.

¶ Alcohol, saturated with soap at ebullition and allowed to cool, forms a yellow and transparent mass, and if it is a soda soap of tallow or suet, it is so transparent that objects can be distinctly seen through it, when it is half an inch thick.

Earthy soaps.—Formed between an aqueous solution of soap and one of the soluble earthy salts; alum, sulphate of magnesia, muriate of baryta and muriate of lime, are good examples.* Except that with basis of magnesia,† they are all insoluble and cannot be used as detergents. Such soaps are formed with hard waters.

Metallic soaps.—Formed in the same manner; solutions of corrosive sublimate, blue, white and green vitriol, and sugar of lead, decomposed by an aqueous solution of soap, are instances; they are insoluble and not detergent.

Plasters were mentioned under the vegetable oils, (p. 434.) Oils unite with metallic oxides, both by trituration and by heat; more easily in the latter mode, and the oxides of lead, mercury and bismuth, are most frequently employed. The most common plaster is made by boiling olive oil 2 parts with litharge 1, in a little water; it is a soft solid.

Soap of ammonia—volatile liniment.—Formed, instantaneously, by simple agitation of strong water of ammonia 1 part, in a vial, with 8 parts of olive oil; or by mingling muriate of ammonia with aqueous solution of soap.

It is advantageously used, in some cases of external inflammation, and of bites of poisonous animals and stings of poisonous insects. In a close vessel it keeps for years, but is decomposed in the air.

Soaps of essential oils.—These are little known; an imperfect combination with oil of turpentine and potassa, is formed by agitation or trituration, and a preparation of this kind, made by an alchemist of the name of Starkey, once had some reputation. (p. 442, note.)

Acid soaps.—Even the acids combine with oils and produce saponaceous compounds, in which the acid properties are very considerably neutralized.‡

Saponification; theory of the process.

In consequence of the discoveries of Chevreul, we can no longer say, as formerly, that the oils simply unite with the alkali.

The theory now to be stated has been, in a great measure, anticipated by the statements already made relative to the peculiar acids developed during the combination of oils with alkalies.

Soaps, then, are definite compounds of those acids with the alkaline bases and a definite quantity of water, while the glycerine or sweet

* See Berthollet's memoir, Nich. Jour. 4to. Vol. I, p. 170.

† This is soluble in alcohol and in fixed oils.

‡ Nitric acid oxygenizes fat; one sixteenth of nitric acid being added to melted lard, the mixture is agitated; nitrous gas and nitrogen rise, and the fat becomes firmer and granular; the acid is removed by washing, and the preparation is used for ointments; it is soluble in alcohol; this is not however mentioned as a soap.

principle, is left in solution. When a hot solution of potassa or soda is added to fat, the solid pearly matter, called margaric acid, is formed, and the eläin becomes oleic acid, and thus a margarate and an oleate of the base are formed in various proportions, according to the nature of the oil. The compounds are in equivalent proportions but differ in different soaps.

Those made with the fat of pork, mutton, beef, &c. contain chiefly stearate, margarate and oleate; human fat, chiefly the two latter; that of the sea hog contains, in addition, the phocerate. The vegetable oils afford the margaric and oleic acids. *The soaps are now regarded as double salts, and the acids vary with the kind of oil.* The soaps are insoluble in the spent ley which dissolves the glycerine. When the solutions of soap are decomposed by stronger acids, e. g. the muriatic, tartaric, or phosphoric, the acids of the oils are separated and generally float. *The stearic, margaric and oleic acids* have been obtained by the distillation of oils and fat or suet, and strong sulphuric acid develops them from the latter; thus they are produced by the agency of alkalis, acids and fire.

The earthy and metallic soaps and the plasters are all governed by the same law; they are margarates, stearates, oleates, &c. of their respective bases. Thénard suggests a doubt whether the volatile liniment is a true soap.*

SEC. VIII.—ACIDS

derived from, or having relation to, animal substances.

Remark.—Several of the acids that have been already described under animal substances, might have been included under the present head, but their properties were more intelligible in the place where they have been introduced.

I. URIC ACID.

1. *Discovered by Scheele,† in 1776; found in urine, and when it is in a healthy state, uric acid always exists in it, generally united to some alkali, and usually to ammonia; in union with soda, it forms a part of gouty concretions; what is called the gravel, consists principally of uric acid; it is of a brick red color, and being little soluble, it is speedily deposited as urine grows cold; adheres so strongly as to require friction to detach it. It forms the yellow calculi, and those that resemble wood in color and appearance, and also the white part of the excrement of birds. The solid urine of birds of prey, as the*

* Chem. 5th Ed. Vol. iv, p. 71, note.

† Called by him the lithic acid, upon the supposition that the urinary concretions, (stones, *lithoi*.) were all formed of this acid.

eagle, and of serpents, as the boa constrictor, is almost entirely uric acid or sub-urate of ammonia.* It is found in the excrement of the butterfly and of the silk worm.

2. Process.

(a.) Dr. Henry's process is to *dissolve the powder of a uric calculus in a solution of potassa; the clear solution is decomposed by muriatic acid, in excess, and the precipitate is washed abundantly and dried at 212°.*†

(b.) *The red, uric deposits from human urine, (not putrefied,) may be substituted; either caustic potash or soda may be used, and on adding the muriatic acid, the uric acid falls, as a gelatinous hydrate, in white flocculi, which become brilliant plates or grains, grey or greenish; it is washed until the water no longer troubles nitrate of silver, and is then dried as above.*

3. Properties.

(a.) When pure, a *white, inodorous, tasteless powder*;‡ soluble in 1720 parts of cold water and 1150 of boiling, but on cooling, most of it precipitates. Dr. Prout found that 10000 of cold water were required to dissolve 1. It reddens litmus; it is insoluble in alcohol.

(b.) *Combines with pure fixed alkalies, added in excess, but does not effervesce with alkaline carbonates; the carbonate of soda is decomposed by boiling with it,§ and a stream of carbonic acid decomposes the urate of potassa; the neutral urates of potassa and soda are not much more soluble than the acid itself.|| The urate of ammonia is soluble in cold water, but more so in boiling.*

(c.) *Uric acid is soluble in the nitric acid, or rather they produce a mutual decomposition, and a pink color;¶ urine gives the same color with nitric acid, owing to the uric acid, and by concentrating the urine, or by dropping in an acid, the latter is often deposited.*

(d.) *On evaporating the nitric solution of uric acid nearly to dryness, it assumes a fine crimson color, which, by the addition of water, becomes deeper and resembles carmine; for this purpose a few drops of nitric acid, slightly diluted, may be mixed in a watch glass with uric acid and evaporated to dryness; the aqueous solution, in a few hours, loses its color irrecoverably.***

(e.) *By repeatedly distilling nitric acid from off the uric, the latter is decomposed, carbonic and nitrogen gases are evolved, prus-*

* Ann. Philos. Vol. vi, p. 78.

† Soda may be used instead of potassa, and the acetic or sulphuric acid may be added to precipitate it.

‡ Dr. Henry suggests that a specimen which he examined might have contained urate of ammonia.

§ Thomson.

|| For Dr. Henry's account of the urates, see Manchester Society's Memoirs, Vol. ii, N. S.

¶ If dilute, the fluid is of a pink color, when concentrated, a deep crimson.—A. A. H.

** Thomson, in Ed. Encyc.

sic acid is disengaged, and the residuary fluid deposits crystals of nitrate of ammonia. Chlorine produces muriate of ammonia, and oxalic and malic acids.

(f.) *Destructive distillation gives a sublimate of a yellow color, containing no uric acid, but a new and peculiar one, combined with ammonia, also a little oil, carbonate of ammonia, prussic acid, water and carbonic acid, and about one sixth of charcoal, remains.*

(g.) *Composition.*—The carbon is, in volume 2, to nitrogen 1, as in cyanogen,* and the hydrogen is in greater proportion than to form water.† The latest analysis of Dr. Prout, gives carbon 6 equiv. = 36 + oxygen 3 = 24 + nitrogen 2 = 28 + hydrogen 2 = 90; and if 2 equiv. of water 18, supposed by Dr. Thomson to be contained in the crystallized acid analysed by Dr. Prout, are deducted, the equiv. of the acid will be 72.

Pyro-uric (cyanic) acid.—*Formed by the action of heat upon uric acid; it is the yellow matter sublimed as stated in (f.); first observed and partially examined by Dr. Henry, and afterwards more fully by Chevalier and Lassaigne.‡*

The aqueous solution of the yellow matter, being decomposed by acetate of lead, the lead is removed by sulphuretted hydrogen, and the filtered and evaporated liquor yields white needle crystals.

Properties.—*Soluble in 40 parts of water, and from boiling alcohol, falls in grains; reddens vegetable blues; sublimes undecomposed, and condenses in white needles; dissolves in nitric acid, and is recovered unchanged; forms salts which are not decomposed by acids, and do not precipitate metallic salts; resembles both succinic and benzoic acids, but differs from both; composition the same as that of the uric acid, but the elements are in different proportions.*

Remark.—As it is now proved that the pyro-uric acid is identical with the cyanic acid,§ any mention of it in this place, might have been omitted, but its connexion with uric acid has induced me to let it remain where it has hitherto stood in systems.

II. PURPURIC ACID.||

1. *Formed by the decomposition of uric acid by the nitric; the red color mentioned in the last article is owing to purpurate of ammonia, for this acid forms purple colored salts, a property which however does not, in strictness, belong to the acid, but to some animal matter, evolved at the same time when the acid is formed.*

* Gay-Lussac, Ann. de Chim. Vol. xcvi, p. 58.

† Berard, Ann. Ch. et de Ph. Vol. v, p. 296.

‡ Ann. Philos. Vol. xvi, p. 25.

§ Dr. Prout, Phil. Trans. 1818.

§ Eng. Quar. Jour. No. 14, p. 426.

eagle, and of serpents, as the boa constrictor, is almost entirely uric acid or sub-urate of ammonia.* It is found in the excrement of the butterfly and of the silk worm.

2. Process.

(a.) Dr. Henry's process is to *dissolve the powder of a uric calculus in a solution of potassa; the clear solution is decomposed by muriatic acid*, in excess, and the precipitate is washed abundantly and dried at 212°.†

(b.) *The red, uric deposits from human urine, (not putrefied,) may be substituted*; either caustic potash or soda may be used, and on adding the muriatic acid, the uric acid falls, as a gelatinous hydrate, in white flocculi, which become brilliant plates or grains, grey or greenish; it is washed until the water no longer troubles nitrate of silver, and is then dried as above.

3. Properties.

(a.) When pure, *a white, inodorous, tasteless powder*;‡ soluble in 1720 parts of cold water and 1150 of boiling, but on cooling, most of it precipitates. Dr. Prout found that 10000 of cold water were required to dissolve 1. It reddens litmus; it is insoluble in alcohol.

(b.) *Combines with pure fixed alkalies*, added in excess, but does not effervesce with alkaline carbonates; the carbonate of soda is decomposed by boiling with it,§ and a stream of carbonic acid decomposes the urate of potassa; the neutral urates of potassa and soda are not much more soluble than the acid itself.|| *The urate of ammonia is soluble in cold water*, but more so in boiling.

(c.) *Uric acid is soluble in the nitric acid, or rather they produce a mutual decomposition, and a pink color*;¶ *urine gives the same color with nitric acid*, owing to the uric acid, and by concentrating the urine, or by dropping in an acid, the latter is often deposited.

(d.) *On evaporating the nitric solution of uric acid nearly to dryness, it assumes a fine crimson color*, which, by the addition of water, becomes deeper and resembles carmine; for this purpose a few drops of nitric acid, slightly diluted, may be mixed in a watch glass with uric acid and evaporated to dryness; the aqueous solution, in a few hours, loses its color irrecoverably.**

(e.) *By repeatedly distilling nitric acid from off the uric, the latter is decomposed*, carbonic and nitrogen gases are evolved, prus-

* Ann. Philos. Vol. vi, p. 76.

† Soda may be used instead of potassa, and the acetic or sulphuric acid may be added to precipitate it.

‡ Dr. Henry suggests that a specimen which he examined might have contained urate of ammonia. § Thomson.

|| For Dr. Henry's account of the urates, see Manchester Society's Memoirs, Vol. II, N. S.

¶ If dilute, the fluid is of a pink color, when concentrated, a deep crimson.—A. A. H.

** Thomson, in Ed. Encyc.

IV. FORMIC ACID.

Originally extracted from the ant, (Formica rufa,) but afterwards supposed to be only a variety of acetic acid, mixed with the malic; or of phosphoric acid and animal matter. It resembles acetic acid in properties, but differs in composition; in this particular it is nearly identical with the oxalic.

It may be formed, by gently heating bi-tartrate of potassa or tartaric acid with black oxide of manganese and water. As the subject is not very important, I dismiss it after citing some authorities.*

The amniotic acid, obtained by Vauquelin, by evaporating the fluid of the amnion, when it fell in white crystals which reddened vegetable blues; it was brilliant, sour, and soluble in warm water and in alcohol; other chemists however, have not succeeded in obtaining it, and its peculiar character is not certain. The fluid contains a little albumen and gelatin, soda, muriate of soda, and phosphate and carbonate of lime; a little sugar of milk has also been found.

The hippuric acid.—This name has been given to a peculiar acid existing in the urine of herbivorous animals. From that of the horse, (*14400*), muriatic acid throws down a yellowish brown precipitate, which is washed, boiled with quick lime and water, and filtered and purified by chloride of lime and charcoal; to the hot liquid a great excess of muriatic acid is added, and on cooling, prismatic crystals appear 3 or 4 inches long, white, shining and translucent, and differing from benzoic acid in form, and in being more soluble in water and in other properties. It contains 1 equiv. of nitrogen, while the benzoic acid contains none; it contains also more carbon and oxygen, and less hydrogen. By sublimation, it affords benzoic acid, which is formed in the process and did not exist previously in the urine as stated at p. 483, of this volume. This correction is made by Leibig,† who remarks that he has not been able to extract the smallest quantity of benzoic acid from the food of horses.

Saccho-lactic acid.—Discovered by Scheele, in 1780, by causing 3 parts of nitric acid to act, with a gentle heat, upon one of sugar of milk; gum is usually substituted, and the acid obtained from it has been called mucous or mucic acid; in either case, the acid precipitates in the form of a white powder, and by washing with water, it is separated from the oxalic and malic acids, which are formed at the same time. It is purified by combining it with ammonia, dissolving in boiling water, filtering, evaporating to dryness, washing with cold water, redissolving in boiling water, and dropping the saturated hot solution into dilute cold nitric acid.‡

* Ann. de Chim. Vol. lxiv, 48; Thomson's Ann. Vol. v, p. 24, and Ann. of Philos. N. S. Vol. iv, p. 310.

† Eng. Quar. Jour. N. S. No. 14, p. 424.

‡ Turner, quoting Prout.

Properties.—A white gritty powder, slightly acid to the taste, and feebly reddening the tincture of turnsol; soluble in 60 parts of boiling water, and deposits small crystals on cooling; decomposed by heat and yields the usual vegetable products, besides a white sublimate, which has been called the pyro-mucic acid.

Composition.—Carbon 33, oxygen 61.5, hydrogen 4.9, (Prout) and with this the analyses of Gay-Lussac and of Berzelius, very nearly agree; its constitution by equivalents is inferred to be carbon 6=36, oxygen 8=64, and hydrogen 5=105 for its equivalent.

The saccho-lactates are of little importance; those of the alkalis are very soluble, and those of the earths so much less soluble, that the alkaline earths, by taking the acid from the alkaline saccho-lactates form white precipitates in strong solutions.

The saccho-lactate of ammonia is decomposed by heat and leaves the acid, while the other salts of this class suffer the acid to be decomposed and leave the base.

PRUSSIC COMPOUNDS.*

Remarks.—It has been already stated, (p. 267, of this volume,) that in 1704,† Prussian blue was accidentally discovered at Berlin. The coloring principle which is produced by the reaction of the elements of blood or other animal matter, when moderately heated with an equal weight of fixed alkali, is capable of being transferred from its union with the latter, so as to precipitate from a solution of a per salt of iron, the fine pigment with which the chemist commences all his experiments on the prussic compounds. Prussian blue is digested with diluted muriatic or sulphuric acid to remove the alumina with which it is mixed, and then it is fit to be used in forming the other prussic combinations. There is a difficulty on the ground of anticipations in beginning the history of these compounds at any particular point. We will begin with the basis of prussic acid. This is obtained from what was formerly called the prussiate of mercury, now the cyanuret, which is formed by boiling together in a sufficient quantity of water, the red oxide of mercury with twice‡ as much prussian blue.

By evaporation, the cyanuret crystallizes in white or yellowish brown crystals, which are prisms of four sides, and from these we obtain the cyanogen, the basis of prussic acid.

CYANOGEN.

From *xavos*, blue, and *γσινοαι*, to produce, because it was supposed to be the basis of Prussian blue; (discovered by Gay-Lussac in 1815.)§

* For fuller notices of the discovery of Prussian blue. see Cooper's Thomson, Vol. ii, p. 221; Alkins' Dict. Vol. ii, p. 251; Thénard's Chem. 5th Ed. Vol. iv, p. 486, and Phil. Trans. 1724. † Thénard—most authors say 1710.

‡ These proportions are preferable to those stated on p. 417, Vol. i.

§ Ann. de Chim. Vol. xcv, and Thom. Ann. Vol. viii, p. 37.

1. *Process.*

(a.) In a small glass retort,* *heat*, by a lamp or a few coals, *very dry cyanuret† of mercury*, it begins to blacken and melt like an animal matter, and then the cyanogen is disengaged in abundance;‡ the sole products are cyanogen gas, volatilized mercury and residuary charcoal;§ but if moist, it furnishes carbonic acid, ammonia and hydro-cyanic or prussic acid.

(b.) At every degree of heat below that which melts the glass, the cyanogen is pure.

2. *Properties.*

(a.) *Cyanogen is a permanent elastic fluid*, at the common pressure and temperature. *Mr. Faraday*, by causing it to be evolved in sealed glass tubes, under its own pressure, obtained it in the form of a fluid, limpid and suffering no change at 0° F.; its sp. gr. was almost 0.9; the pressure was not over 3½ atmospheres at 45° F.; when the tube was opened, it became again cyanogen gas, and its evaporation produced considerable cold.||

(b.) *Odor undefinable*, but is lively and penetrating.

(c.) *Inflammable, and burns with an intensely beautiful bluish flame mixed with purple*; the appearance of the flame is very peculiar; no water is formed during its combustion, even when the receiver is cooled by ice, (Davy,) but carbonic acid is produced and nitrogen disengaged.

(d.) *Density by experiment, air being 1. is 1.8064; by calculation, it is 1.8055*; 100 cubic inches, at 60° F., weigh 55 grs.; it supports a very high temperature without decomposition.

(e.) *Water*, by agitation at 60° F. *absorbs almost 4½ volumes*, and the taste of the solution is sharp and penetrating. Ether and oil of turpentine, about as much as water; alcohol absorbs 23 times its volume.

(f.) *Tincture of turnsol is reddened by it*, and when the absorbed gas is expelled by heat, the color returns and some carbonic acid¶ is expelled.

* As the heat which readily decomposes the cyanuret is very nearly that which melts the glass, I usually coat a small retort thinly with fire lute, applied by the hand and dried, at the moment, by the open fire; then the experiment will never fail; the volatilized mercury collects, in myriads of globules, which are distinct when seen with a magnifier, although to the naked eye the glass may appear only clouded with a gray sublimate.

† Or bi-cyanuret, as it has two equivalents of cyanogen.

‡ The cyanuret of silver answers also, but that of mercury is the best.

§ A good deal of the cyanuret is volatilized.

|| Mr. Bussy succeeded in solidifying cyanogen by cold alone; Ann. de Chim. et de Phys. Vol. xxvi, p. 68.

¶ The result of a partial decomposition and the probable cause of the reddening; other acids may have been also formed.

(g.) *Volatilized phosphorus, sulphur and iodine, produce no change in cyanogen, nor does hydrogen, either by heat or by the electric spark.*

(h.) *Copper, gold and platinum, do not combine with it, but even at almost a white heat, decomposes it, becomes partially brittle, and is slightly covered with coal; nitrogen is also given out.*

(i.) *With potassium, in the cold, there is no action; with the heat of a spirit lamp, there is incandescence, cyanuret of potassium is formed, and as much gas is absorbed as equals the volume of hydrogen which potassium would expel from water.*

(j.) *The compound of cyanogen and potassium is yellowish, dissolves in water without effervescence, and forms hydro-cyanate (prussiate) of potassa. Cyanogen unites with a number of other metals and forms cyanurets.*

Composition.

(k.) *Cyanogen, 1 volume, inflamed in Volta's eudiometer, with 2½ volumes of oxygen,* produced 2 volumes of carbonic acid, and 1 of nitrogen was evolved. Half a volume of oxygen gas was left; if the gas is pure no water is formed, and of course, there is no hydrogen in cyanogen.*

(l.) *It contains two volumes of vapor of carbon, and one of nitrogen condensed into one volume. The sp. gr. of nitrogen is .972, and that of the vapor of carbon .416, which $\times 2 = .832$, and the sum gives the weight at 1.804, which is very near the numbers already stated. The equivalent of cyanogen is 26, composed of 1 equivalent of nitrogen, 14, and 2 of carbon, 12. It is therefore, a bi-carburet of nitrogen.*

(m.) *Cyanogen gas is rapidly absorbed by aqueous solution of potassa, and this, with one of iron slightly oxidized, produces prussian blue by the addition of an acid. The compounds with soda, baryta and strontia, act in the same manner.†*

(n.) *The metallic oxides do not produce the same changes on cyanogen as the alkalis; the proto-sulphate of iron, decomposed by just alkali enough to saturate the acid, absorbs cyanogen but without forming prussian blue, although the same solution produced it, just before, when added to the compound of cyanogen and an alkali.*

(o.) *Cyanogen is not an acid, but it is distinctly the basis of several. Its compounds are not acid, and are called cyanurets.*

PRUSSIC OR HYDRO-CYANIC ACID.

I. NAME.—*The first name from Prussian blue—the second from the hydrogen and cyanogen, of which it is composed; see its composition.*

* In Gay-Lussac's early experiments, the explosion broke the tube.

† See Gay-Lussac's views as to the nature of these compounds, *Ann. de Chim.* Vol. xcv, p. 190, and sequent.

II. DISCOVERY.—By Scheele, in 1782, but his acid was dilute. It was first obtained pure by Gay-Lussac, in 1815,* and several other of the ablest chemists of the day have been engaged in the investigation of its properties.†

III. PROCESSES.

1. *The cyanuret (prussiate) of mercury is decomposed by muriatic acid.*

(a.) *Apparatus.*—A tubulated retort, with a horizontal tube, two feet long, containing in the first third part, pieces of white marble, to detain any volatilized muriatic acid; the remaining two thirds contain fused muriate of lime to absorb the aqueous vapor; a small receiver is adapted, surrounded with ice, or better with a freezing mixture.

(b.) *Strong muriatic acid, 2 parts,‡ is then added to 3 of the cyanuret of mercury; a gentle heat is applied and the prussic acid, condensing first on the marble, is driven onward by heat and collects on the muriate of lime, and lastly in the receiver.*

2. As the product from the above process is small, Vauquelin substituted the following. A similar arrangement was made of the *cyanuret of mercury, in a glass tube, with muriate of lime and carbonate of lead,§* in the order named, and *sulphuretted hydrogen gas*, from sulphuret of iron and diluted sulphuric acid, *was passed slowly over the cyanuret, which was blackened; heat was applied to drive the acid along into the receiver, chilled by ice and snow; this process is easy and productive.||*

3. *A dilute acid is easily obtained by passing sulphuretted hydrogen gas through a solution of 60 grs. of cyanuret of mercury in 1 oz. of water; after shaking it with carbonate of lead, to absorb the excess of sulphuretted hydrogen, it is filtered. For medical use, 1 lb. of the cyanuret is distilled with 6 lbs. of water and 1 lb. of muriatic acid, and when 6 pints have passed, the sp. gr. will be .995.—Brande.*

IV. PROPERTIES.

(a.) *A colorless liquid, highly odorous, with the smell of peach blossoms; taste, at first cooling, then burning; highly narcotic and poisonous.*

(b.) *Sp. gr. at 44½° is .7058, at 64° .6969; boils at 79° Fahr., freezes at 0°; melts at 5° Fahr. and crystallizes regularly, like the*

* Ann. de Chim. lxxxvii, 128, and xv, 136.

† Ann. de Chim. lx, 225; Ann. de Chim. et de Phys. i, 120; xii, 372 and 378; ix, 113, and xv.

‡ There must be an excess of the cyanuret, that the muriatic acid may all be engaged.

§ To decompose any excess of sulphuretted hydrogen gas.

|| It yields one fifth as much prussic acid as the cyanuret of mercury weighs, and is finished, when the cyanuret is all blackened and the smell of sulphuretted hydrogen begins to be perceived in the receiver.

fused nitrate of ammonia; in consequence of the cold produced by its own evaporation, it congeals, even at 68° , and the vapor supports 16 inches of mercury; in warm weather its vapor may be collected over mercury, and if the crystallized prussiate (ferro-cyanate) of potassa is gently heated with dilute sulphuric acid, the same vapor or gas may be collected; it quintuples the volume of any gas with which it is mixed.

(c.) Although repeatedly rectified from marble, it feebly reddens litmus, and the color is restored as the acid evaporates.

(d.) *The liquid acid forms prussian blue, both with iron and its oxide.*

(e.) *Its vapor, if inhaled, is very noxious*; it speedily kills small animals; even when mixed with common air, it produces giddiness, head ache and fainting;* the medicinal acid exhales a vapor, the odor of which produces sensible depression. *The strong acid kills small animals instantly*; even a drop of it, applied to the tongue or the eye of a rabbit or of a vigorous dog, is fatal. A German chemist is reported to have lost his life by receiving a drop of it upon his arm.

It is stated by most authors, that muscular irritability is entirely destroyed in animals poisoned by the prussic acid. Prof. Torrey and Dr. W. H. Ellet, have found by experiment, that the stimulus of Voltaic electricity produces as violent muscular contractions in these cases, as when life is destroyed by any other means.†

Composition.

(f.) *The vapor is inflammable and*, as Gay-Lussac found, *determinates with oxygen gas*; 100 measures require 125 of oxygen and 100 of carbonic acid, and 50 of nitrogen are obtained; as there were 25 measures more of oxygen employed than the carbonic acid contains, and as they go entirely to form water, there must have been 50 measures of hydrogen. *Potassium, heated in the vapor of prussic acid, combines with its base, the cyanogen*, and forms a cyanuret of potassium, *while hydrogen gas is evolved*, equal to half the volume of the vapor. The acid is therefore composed of equal volumes of

* In preparing the acid of Scheele, although the apparatus was under a well drawing chimney, both myself and my assistants have been affected in the manner mentioned in the text; and on another occasion the vapor from a bottle of the medicinal acid of Paris, accidentally broken on the floor, although covered and disposed of as quickly as possible, produced alarming effects, fainting, loss of pulse, &c. which were not entirely removed in several days. Am. Jour. Vol. ii, p. 93, note.

† Dr. Torrey says, after all signs of sensation have disappeared, I have found the heart to contract by the slightest touch, especially when the contact was made with a piece of metal. This effect could often be produced nearly half an hour after apparent death. But animals sometimes remain a long time insensible and apparently dead, under the influence of prussic acid, and then recover, either spontaneously, or by the agency of antidotes.

cyanogen and hydrogen, united without condensation, and the cyanogen, as heretofore stated, consists of 2 vols. of carbon vapor and 1 vol. of nitrogen, condensed into 1 volume.

(g.) Gay-Lussac passed the vapor of this acid through an ignited porcelain tube, containing iron, and concluded that it contains no oxygen, but is composed of 1 vol. of carbon vapor, $\frac{1}{2}$ a vol. of hydrogen and $\frac{1}{2}$ a vol. of nitrogen or azote, condensed into 1 volume. As the cyanogen and hydrogen are united without condensation, we obtain the specific gravity of the vapor of hydro-cyanic acid by adding together the specific gravities of these gases and dividing by 2, e. g. $1.8055 + .0694 = 1.875 \div 2 = .9375$, and experiment gives it at .9476. By weight, the composition of the vapor is cyanogen $100 + 3.846$ hydrogen, corresponding to 2 equiv. of carbon $12 + 1$ of nitrogen $14 + 1$ of hydrogen $= 27$, its equivalent. It appears then that the addition of 1 equiv. of hydrogen to cyanogen, forms hydro-cyanic or prussic acid.

(h.) *As an animal substance, prussic acid is distinguished by its large portion of nitrogen, the small proportion of hydrogen and the entire absence of oxygen.*

(i.) The nitrogen and carbon united, form the peculiar basis of this acid, and hydrogen sustains the same relation to it as it does to chlorine, iodine, bromine and sulphur, since, with all those substances, it forms hydracids.*

(j.) *Prussic acid is very liable to decomposition*; even in close vessels it is sometimes decomposed in one day, and can rarely be kept over fifteen.†

(k.) *Iodine and phosphorus may be volatilized without change in prussic acid vapor.*

(l.) *By iron, at ignition, it is decomposed*; it operates simply by transmitting heat, for the carbon is deposited and not combined, except partially, with the iron; platinum decomposes the vapor in the same manner.

(m.) *Baryta, heated in the prussic or hydro-cyanic acid, yields its barium to the cyanogen* of the acid to form a cyanuret of barium; the hydrogen of the acid and the oxygen of the earth unite to form water.

(n.) *With potassa and soda the results are similar.*

(o.) *Hydro-cyanic acid is decomposed by oxide of copper*; water is evolved and a cyanuret of copper results.

* That is to say, acids in which hydrogen sustains the same relation to the base that oxygen does in all other acids.

† It becomes reddish brown, and if the vessel is not perfectly tight leaves only a charry mass. I have, however, kept the medicinal acid of Paris in a dark place, unchanged for several years; most of the bottles remained limpid, but there was generally prussian blue deposited at the bottom, and in one bottle the acid was decomposed and the glass was lined with a black film.

(p.) *With red oxide of mercury, the action, aided by heat, is violent, and cyanuret of mercury is formed.*

V. MISCELLANEOUS FACTS.—*Prussic acid is easily recognized by the distinct smell of peach blossoms, perceived even when it is very dilute, but there is besides, a peculiar heavy odor usually compared to that of bitter almonds, but which cannot be well described. If a bottle of this acid is made to approach the nostrils, it should be done with great care, for the odor, even of the medicinal acid, produces depression and vertigo. A bird, brought near a vial of the acid, fell down, killed by the vapor alone.—G. L.*

*Prussic acid exists in the vegetable kingdom; the peculiar smell of bitter almonds, peach flowers, (and leaves,) the leaves of the laurel, Lauro-Cerasus, and other vegetables with the same odor, is owing to prussic acid. Peach, laurel and almond water, although used in families as condiments, are only diluted prussic acid, and are therefore, poisons. The acid in them may be neutralized by combination with lime or an alkali, when it will precipitate prussian blue from a solution of iron. Persons have been often killed by taking laurel water, and cattle are poisoned by eating the leaves. Prussic acid is obtained also from peach and apricot kernels. The bark of the *Prunus Padus* contains much of it; water distilled from it kills animals. In some oil distilled from peach leaves, which had stood eight years undisturbed in a close vial, Brugnatelli found the prussic acid separated and crystallized; on combining it with potash it gave prussian blue with iron.**

Medicinal acid.—There is so much diversity in the strength of this acid as found in the shops and as made by the process of Scheele, that it is recommended† to prepare the acid of Gay-Lussac, and then to dilute it with 6 times its volume, or 8.5 times its weight of water; this is the medicinal acid of Magendie. It may be better kept dissolved in 6 times its volume of alcohol, with which it more readily unites than with water.‡

The strength of different specimens may be ascertained by distilling equal quantities separately into a solution of nitrate of silver; the strength will be directly as the quantity of the precipitated cyanuret of silver.§ Dr. Ure prefers the pulverized peroxide of mercury as a test of the strength of the acid, the real acid being equal to one fourth of the oxide dissolved. Let a solution of green sulphate of iron, after being mixed with the liquid supposed to contain prussic acid, be decomposed by potassa added slightly in excess and exposed for a few minutes to the air; then add

* Ann. de Ch. Vol. xcvi, p. 97.

† Magendie's Formulary.

‡ If the strongest acid is agitated with 10 or 12 times its weight of water, it collects on the surface like an oil or ether, but is dissolved by additional agitation.—Magendie's Formulary.

§ Dr. Faust in Am Jour. Vol. xix. p. 71.

a little dilute sulphuric or muriatic acid, which will dissolve all the precipitate that is not in the condition of prussian blue, and the amount of the latter will indicate the proportion of prussic acid. This test is applied also in the case of poisoning. The organs into which the acid has been conveyed have its odor; portions of them are cut up, and water, slightly acidulated with sulphuric acid, is distilled from them at 212° , and then the fluid is examined by the above test which will detect $\frac{1}{1000}$ of the acid, from 1 to 2 or 3 days after death. The per sulphate of iron is directed to be used by M. Lassaigne,* but Dr. Turner states that no prussian blue will be formed if the iron is at the maximum of oxidation, and that the presence of the protoxide is indispensable.†

The sulphate of copper is a still more sensible test. It is treated exactly as above, and acquires a milkiness even with $\frac{1}{1000}$ of the acid.

Medical use of prussic acid.—Its principal power appears to consist in abating irritative action. It has been strongly recommended in the first stages of phthisis, in asthma, whooping cough, &c. But as the opinions of the faculty do not appear to be entirely settled in regard to the utility or even safety of this most powerful agent, I shall add nothing more on this head, but refer the reader to authorities.‡ For the medical recipes, see the same.

OTHER COMBINATIONS OF CYANOGEN.

Remarks.—It is observed that this base, although compound, has a name in analogy with those of simple bodies. Its combinations with the elements justify this nomenclature, for it produces many compounds with the undecomposed bodies; several of them are acid, and in describing them we must anticipate some facts that have not yet been explained.

I. COMBINATIONS OF CYANOGEN WITH OXYGEN.§—CYANIC ACIDS.

Three combinations of this kind are known, and they are all acid; two appear to consist of the same elements united in the same proportions;|| they are however remarkably different in their properties, or

* See the abstract of M. Lassaigne's memoir on the modes of discovering prussic acid, Ann. de Ch. et de Ph. Vol. xxvii, p. 200.

† With the protoxide only, no prussian blue is formed, until the greenish white precipitate acquires oxygen from the air, or an acid is added.

‡ See Magendie's Formulary; Coxe's Dispensatory; Am. Jour. Vol. II, p. 81; Id. Vol. III, p. 182, &c., and the various Medical Journals and modern Medical Elementary books.

§ See a good sketch of the cyanic acids, Ann. de Chim. et de Phys. Vol. xxxviii, p. 379.

|| As is supposed to be the fact also with some of the compounds of carbon and hydrogen, Vol. i, p. 399.

at least in the combinations which they form, for they are scarcely known in an isolated state.

The third acid contains the same elements, but the oxygen is double to that existing in the other two. They might all be called cyanic acid, but to avoid confusion, I will denominate them,

1. *The Cyanic (or cyanous) Acid of Wöhler;*
2. *The Fulminic Acid of Liebig;*
3. *The Cyanic Acid of Serullas.*

I. *Cyanic Acid, (of Wöhler.)*

1. *Preparation.*

(a.) *By passing cyanogen gas through a solution of pure fixed alkali, e. g. of potassa; cyanate and hydro-cyanate of the alkali are formed by the elements of water, as happens with chlorine, iodine, bromine and sulphur; but this method is not eligible, because the two salts are not easily separated.*

(b.) *By a low ignition of ferro-cyanate (prussiate) of potassa, and an equal weight of peroxide of manganese, both in fine powder; oxygen is transferred from the oxide to the cyanogen and it thus becomes an acid and unites to the potassa to form a cyanate, which is separated by boiling the mass with alcohol of 86 per cent. from which, as it cools, the salt precipitates in small tabular crystals.**

(c.) *By passing sulphuretted hydrogen gas through cyanate of silver suspended in water, stopping before the cyanate is all decomposed,† the cyanic acid may be liberated.‡*

2. *Properties.*

(a.) *It reddens turnsole, is acid to the taste and exhales a peculiar odor, the same that is perceived when a cyanate is decomposed by an acid.*

(b.) *But its properties are little known, because it is very difficult to obtain the acid in a separate state; the acid is decomposed, simply by boiling an aqueous solution of the salt containing it; carbonic acid and ammonia being produced.*

(c.) *The other salts are most easily formed by double exchange with the cyanate of potassa; the cyanate of baryta is soluble; the cyanates of lead, mercury and silver, are insoluble.*

(d.) *Composition.*—Cyanogen, 1 equiv. $26 + 1$ of oxygen $8 = 34$, or taking the elements of cyanogen separately, carbon 2 equiv. $= 12 +$ nitrogen 1 equiv. $14 = 26 +$ oxygen one, $8 = 34$, as above.

II. *The fulminic acid.*—This has been already mentioned under the fulminating mercury and fulminating silver. (See pp. 325, 339.)

* Wöhler, Ann. de Chim. et de Phys. Vol. xxvii, p. 196.

† Because, otherwise the cyanic acid would be decomposed.

‡ Liebig, Ann. de Chim. et de Phys. Vol. xxxiii, p. 208.

The fulminic acid yields, by decomposition, the same gaseous products as those afforded by the cyanic acid.

Dr. W. H. Ellet, regards the fulminating silver as an argento-cyanate, and the fulminating mercury as a mercurio-cyanate; in each of these compounds the metal being an element both in the acid and in the base. For his reasons we must refer to his ingenious paper in the American Journal of Science, Vol. xviii, p. 336.

We have room to cite only the numerical results which he obtains by distributing the equivalent numbers, in accordance with his theoretical views, and in analogy with the composition of prussian blue, as viewed by him.

	{	2 atoms cyanogen	52,	17.93
Argento-cyanic acid,		1 " silver	110,	37.93
		1 " hydrogen	1,	.34
		1 " silver	110,	37.93
Oxide of silver,	{	or per cent.		
Water,	{	1 " oxygen	8,	2.76
		1 " oxygen	8,	2.76
		1 " hydrogen	1,	.34
				290
				99.99

The two views are thus compared—

<i>Hypothetical constitution.</i>		<i>Experimental constitution.</i>
In acid.	In base.	
Silver, 37.93 +	37.93 = 75.86	Silver, 72.187
In base.	In water.	
Oxygen, 2.76 +	2.76 = 5.52	Oxygen, 5.341
In acid.		
Cyanogen, 17.93 +	— = 17.93	Cyanogen, 17.160
In acid.	In water.	
Hydrogen, 0.34 +	0.34 = .68	Loss, 5.312
		100.000
		99.99

Dr. Ellet remarks, that if the loss of nearly $5\frac{1}{2}$ per cent. in the analysis were distributed proportionately over all the constituents, and due allowance made for the hydrogen undoubtedly present, then the hypothetical and experimental numbers will be almost identical.

*From fulminating silver, lime water throws down oxide of silver, and from the remaining fluid, nitric acid precipitates the argento-cyanic acid,** as a white powder soluble in water, especially if hot;

* Other alkaline bodies will effect this decomposition; ammonia however dissolves the oxide of silver and forms the fulminating compound of Berthollet, which is still more violent.

it crystallizes, reddens litmus, forms fulminating salts with bases, as with baryta, strontia and magnesia, and with oxides of zinc, iron, copper, mercury, &c.

It will be perceived that the difference between this view and that already presented, (p. 339, of this volume,) is, that in the one case the silver is regarded as existing altogether as a base, and in the other, as constituting, in part, an element of the acid.

III. *The Cyanic Acid of Serullas.*—Strictly, this acid should be mentioned under the head of chlorine and cyanogen, but the statement may be made intelligible in this place.

1. *Preparation.*—*The per-chloride of cyanogen is decomposed by hot water, and the results are muriatic acid and cyanic acid*, derived from the elements of water, the hydrogen going to the chlorine and the oxygen to the cyanogen, to form cyanic acid; *it is obtained by evaporation, which expels the muriatic acid.*

2. *Properties.*—*White, solid, the crystals are rhombs, if they are formed from a concentrated solution—needles, if from sublimation*; it can be redissolved and recrystallized without change, and even hot nitric acid is inert in relation to it, and sulphuric acid dissolves it without change; if dry, its decomposition leaves charcoal; otherwise ammonia and carbonic acid are formed. *This acid is so stable that it is even bleached and rendered brilliant by boiling it in nitric acid.* It forms well defined cyanates, and that of baryta being decomposed by sulphuric acid, the cyanic acid is again liberated unchanged.

3. *Composition.**—By careful analysis by its discoverer, this acid consists of cyanogen 1 equiv. 26 + oxygen 2, 16 = 42, its equiv.

Recapitulation.—It is obvious, that agreeably to the views of M. Serullas, the acid of Wöhler, with 1 equiv. of oxygen and 1 of cyanogen is, in relation to the one just described, a cyanous acid, as the latter is truly the cyanic, and their compounds are of course correctly called cyanites and cyanates.

If the acid of Leibig and Gay-Lussac is really composed of 1 equiv. of cyanogen and 1 of oxygen, as cited in this volume, p. 339, it is also a cyanous acid, but an anomalous one. If it contains a metallic ingredient, then it is a different acid, and should be removed from the cyanic acids.

Artificial Urea.—This was mentioned at the conclusion of the article Urea, page 570 of this volume. It was a singular and unexpected result, obtained by Wöhler, with the cyanic acid, which we have already cited under his name.

* For many details and interesting facts, see the memoir of M. Serullas, *Ann. de Chim. et de Phys.* Vol. xxxviii, p. 381.

Preparation.—By double decomposition, by muriate of ammonia and cyanate of silver; or by single decomposition, by cyanate of lead and liquid ammonia. In this second process, the oxide of lead is liberated and a compound is obtained, in colorless rectangular prisms. In their properties, they are identical with urea, and their composition is exactly the same; they give the same results in analysis as cyanate of ammonia, provided 1 equiv. of water is supposed to exist in that salt.

Still the artificial urea, although from the mode of its formation it would appear that it contains only cyanic acid and ammonia, yields neither, by chemical agents. Potassa does not evolve ammonia, nor do the stronger acids give carbonic acid and evolve cyanic acid, with the peculiar odor which appears when the cyanates are decomposed by a stronger acid. The artificial urea gives no precipitate with salts of lead or silver.*

CHLORIDE OF CYANOGEN.

Omitting the earlier and less correct views in regard to this subject, especially those which relates to the, so called, oxy-prussic and chloro-cyanic acid,† which seem to have been mixtures of muriatic acid, carbonic acid and chloride of cyanogen, we will state the results obtained in relation to the latter.

I. CHLORIDE OF CYANOGEN.

1. *Preparation.*—Powdered cyanuret (prussiate) of mercury is moistened and placed in the dark, in a stopped bottle of chlorine gas, which, in 7 or 8 hours, loses its color; the cyanuret of mercury (excepting only what was intentionally left in excess) is converted into corrosive sublimate (bi-chloride of mercury) and a gaseous chloride of cyanogen, or cyanuret of chlorine, with some portion of common air and of muriatic acid gas and cyanogen, fills the vessel.‡

2. Properties.

(a.) The purification of the cyanuret of chlorine, depends upon the fact that it congeals and forms crystals at $0^{\circ} F.$ by the application of ice $2\frac{1}{2}$ parts and salt 1. For the details of the manipulation, I must refer to the original memoir, (cited below;) it will be sufficient to say that the frozen chloride of cyanogen is dried by the introduction of muriate of lime; it is again congealed, the bottles are filled with mercury and the chloride, by adapted tubes, is conveyed, in the gaseous form, into inverted vessels filled with mercury; for this purpose, the bottles are gently warmed by a few coals, brought near to, but not into contact with the glass.

* Wöhler, in Ann. de Ch. et de Ph. Vol. xxxvii, p. 330.

† See Gay-Lussac's memoir, Ann. de Chim. Vol. xcv, and the sketches in Henry's and Turner's Chem.

‡ Serullas, Ann. de Ch. et de Ph. Vol. xxxv, p. 291.

(b.) *This chloride, as already stated, is solid at 0° F.; crystallizes in long needles; melts between 5° and 10°, is then liquid, and so remains in sealed tubes, under a pressure of 4 atmospheres, created by its own vapor, at the temperature of 68° F.* Under the common pressure, it becomes a colorless gas at 10.5° to 11° F.*

(c.) *Taste caustic; odor offensive and irritating to the eyes; very poisonous.*

(d.) *Very soluble in water and in alcohol; the former absorbs 25 and the latter 100 volumes, at 68°; the solutions are not acid and the gas is recovered by boiling.*

(e.) *Alkalies decompose its solution, evolving carbonic acid gas, when an acid is added. Sulphate of iron added to its solution, and then potassa, and an acid, produces a green color, but not if these agents are used in the reverse order.*

(f.) *Composition.*—Chlorine 1 equiv. 36 + cyanogen 1 equiv. 26 = 62.

II. PER-CHLORIDE OF CYANOGEN.

1. Preparation, &c.

M. Serullas,† the discoverer, prepared it by pouring 15.5 gr. of the prussic acid of Gay-Lussac (anhydrous hydro-cyanic acid) into a bottle containing 61 cubic inches of dry chlorine. The bottle being stopped and exposed to the light, the acid is gasified, the color of the chlorine fades, and after some hours, a colorless liquid, like water, lines the vessel, grows thicker and becomes a white solid, mixed with shining crystals; most of the per-chloride is formed in twenty four hours. For various details of manipulation, I must refer to the memoir cited below.

2. Properties.

(a.) After being washed, dried and distilled, the per-chloride of cyanogen is in needle crystals, white and brilliant; it has, especially when hot, a penetrating odor, which excites tears; its taste is slightly pungent. Sp. gr. 1.320; fusing point 140°, boiling point 190°;‡ it exhales muriatic acid, after being kept for some time.

(b.) Sparingly soluble in cold water, but more so in hot; by the former it is slowly, by the latter, rapidly decomposed, forming muriatic and cyanic acids; very poisonous; 1 gr. dissolved in alcohol and placed in the throat of a rabbit proved instantly fatal.

(c.) In the aqueous solution, potassa forms muriate and cyanate of potassa, which are obtained by evaporation; nitrate of silver precipitates chloride and leaves cyanate of silver in solution, in the nitric

* Id. p. 337.

† Ann. de Ch. et de Ph. Vol. xxxviii, p. 370.

‡ It is not said in the memoir, whether these degrees are centigrade, as is usual in French writings.

acid; *potassium flames with the dry per-chloride*, and forms chloride and cyanuret of potassium.

(d.) *Composition*.—Chlorine 2 equiv. 72 + cyanogen 1 equiv. 26 = 98.

It will be remembered that the cyanic acid, with two equivalents of oxygen, (already described,) is formed from the action of boiling water* upon the per-chloride.

IODIDE OF CYANOGEN.

1. *Preparation*.†—M. Serullas ground rapidly together 2 parts of dry cyanuret of mercury and 1 of iodine, and placed them in a wide mouthed vial, which was gently heated. As the cyanuret begins to be decomposed, the violet vapors of iodine are succeeded by white flocks, and the vial being placed under a large glass receiver,‡ they are condensed and appear like cotton; they are resublimed, at a very gentle heat, to free them from adhering cyanide of mercury. If the vial, when the sublimate is rising, remains uncovered, the cotton-like tufts float in the air, in the same manner as the white sublimate of oxide of zinc.

2. Properties.

(a.) *In white needle crystals; smell and taste pungent; excites tears; sinks in sulphuric acid; soluble in water and more so in alcohol; not acid; decomposed at a red heat*, but sustains, unaltered, a heat above 212° ; *on burning coals exhales violet vapors*; strong solution of potassa forms with it, hydro-cyanate and hydriodate of that base; this solution gives, after the addition of a little muriatic acid, a beautiful green precipitate, with proto-sulphate of iron.

(b.) *Nitric acid has no action*; sulphuric slowly decomposes it, precipitating iodine; muriatic does the same and forms hydro-cyanic acid. *Aqueous sulphurous acid, in drops, liberates iodine* from the crystals and forms hydro-cyanic acid, but the iodine is dissolved by more of the acid; dry sulphurous acid has no action, and water is therefore the agent when it does act. It is much less poisonous than might be expected from its constitution.

(c.) *Composition*.—Iodine 1 equiv. 125 + cyanogen 1 equiv. 26 = 151.

BROMIDE OF CYANOGEN.

This was formed by M. Liebig, but little need be said of it, as the process and properties are extremely similar to those of the preceding compound.

* See p. 602, of this volume.

† M. Serullas, apprehending difficulty in making the combination, gave himself unnecessary trouble in operating under pressure in glass tubes. See his memoir, *Ann. de Ch. et de Ph.* Vol. xxvii, p. 184.

‡ M. Serullas has stated various details in the manipulation, for which I have not room.

Moistened cyanuret of mercury, 2 parts, chilled by cold water or better by a freezing mixture, is covered by 1 part of bromine; there is much heat, and bromide of mercury and bromide of cyanogen are formed; the latter sublimes, and is condensed in long needles or cubes. In properties it is almost identical with iodide of cyanogen, but it is more volatile.

*It is excessively noxious; a rabbit was killed instantly by a grain dissolved in water and placed in his throat.**

In relation to cyanogen there is a strong analogy in the action of chlorine, iodine and bromine, in as much as they all produce cyanides or cyanurets, and also by the action of water or of its elements, they form peculiar acids.

CYANURET OF POTASSIUM.

The direct combination of these bodies has been already mentioned under cyanogen, and it is again named, that we may, by having it in view, pass the more intelligently to other compounds.

It was formed by Mr. Robiquet, by heating to redness, for a good while, the ferro-cyanate† (prussiate) of potassa; if carefully managed, the acid is destroyed and cyanuret of potassium remains, mixed with carbon and iron. If correctly done, the aqueous solution, leaving the carbon and iron, will be colorless, and will not precipitate prussian blue from an acid solution of a per salt of iron. The cyanuret of potassium is fusible, and when kept dry, is not liable to change.‡

Composition.—Cyanogen, 1 equiv. 26, + potassium, 1 equiv. 40 = 66, its equiv.

HYDRO-CYANATES,‡ (simple prussiates.¶)

Salts formed between prussic acid and the bases.

1. The cyanuret of potassium can exist only in the dry state; when dissolved in water, it appropriates the elements of that fluid and forms hydro-cyanate of potassa.

The hydro-cyanates are formed also, by combining prussic acid (the hydro-cyanic,) with the bases.

2. Such compounds, with alkaline or other bases, were formerly called (for reasons that will soon appear,) simple prussiates; when with an alkaline base, the salt is always alkaline; soluble in water and alcohol; with salts of protoxide of iron gives an orange colored

* T. and Edin. Jour. Sci. No. xiii, p. 189.

† According to Dr. W. H. Ellet, it is when anhydrous, a compound of cyanuret of iron and cyanuret of potassium, Am. Jour. Vol. xviii, p. 329.

‡ These salts would have been introduced immediately after the prussic acid, had it not been that they are more intelligible in connexion with the ferro-cyanic acid and its salts.

§ Dissolve the pure bi-cyanide of mercury in pure water, and add a solution of hydro-sulphate of potash so long as a black precipitate falls, the clear liquor is a solution of hydro-cyanate of potassa.—A. A. HAYES. ¶ Of the old nomenclature.

precipitate, becoming in the air, green and then blue; with peroxide of iron giving a blue which becomes deep blue; *decomposable by a heat of 212° , also by weak acids* and even by the carbonic acid.

3. *The cyanurets of the other alkaline and earthy bases are formed in a manner similar to that of potassium*, and like the iodides, chlorides and bromides, they all pass, by the action of water, to the state of hydro-cyanates of their respective bases.

4. *The hydro-cyanate of potassa possesses the same powers over the animal economy as the prussic or hydro-cyanic acid, and being much less liable to decomposition, has been proposed as a medical substitute* for that very fugitive acid.

5. The hydro-cyanates of those bases whose cyanurets are insoluble, are easily formed by double decomposition between their soluble salts and the hydro-cyanate of potassa.

FERRO-PRUSSIC OR FERRO-CYANIC ACID.—FERRO PRUSSIATES OR FERRO-CYANATES.—DOUBLE PRUSSIATES.

Introductory statement.

1. *By boiling an alkali with prussian blue, a triple* prussiate of alkali and iron is formed*; it is neutral; insoluble in alcohol; forms prussian blue with the peroxide of iron; gives a reddish brown precipitate with peroxide of copper; is not decomposable at 212° , nor by the carbonic and other weak acids.

2. *These peculiarities were attributed to the agency of iron existing in the acid*, although iron cannot be detected by tests, such as the hydro-sulphurets, the gallic acid, the succinates, &c.; still the iron remains with the prussic acid when it is transferred from one base to another.†

3. Mr. Porrett, of the Tower of London, found that *when triple prussiate of soda was galvanized, the soda nearly pure, appeared at the negative pole and the acid and iron or oxide of iron at the positive*, the latter, apparently as an element of the acid which there suffered decomposition; a part was volatilized, as common prussic acid, and a part was precipitated with the iron (now become a base,) in the form of Prussian blue.

4. Mr. Porrett inferred, that *the iron* in the triple prussiates, is not a base, but that *with the elements of the prussic acid, it forms a new and stronger acid*; and this is the view now generally admitted among chemists.

FERRO-PRUSSIC OR FERRO-CYANIC ACID.

1. *Preparation.*

(a.) *By tartaric acid.*—With Mr. Porrett, we dissolve 50 grains of crystallized prussiate or ferro-cyanate of potassa in 2 drachms of pure

* Formerly called *triple prussiate*, and this term is occasionally used as in the text.

† See Mr. Porrett's memoirs in the Phil. Trans. 1814 and 15.

Moistened cyanuret of mercury, 2 parts, chilled by cold water or better by a freezing mixture, is covered by 1 part of bromine; there is much heat, and bromide of mercury and bromide of cyanogen are formed; the latter *sublimes, and is condensed in long needles or cubes*. In properties it is almost identical with iodide of cyanogen, but it is more volatile.

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In relation to cyanogen there is a strong analogy in the action of chlorine, iodine and bromine, in as much as they all produce cyanides or cyanurets, and also by the action of water or of its elements, they form peculiar acids.

CYANURET OF POTASSIUM.

The direct combination of these bodies has been already mentioned under cyanogen, and it is again named, that we may, by having it in view, pass the more intelligently to other compounds.

It was formed by Mr. Robiquet, by heating to redness, for a good while, the ferro-cyanate† (prussiate) of potassa; if carefully managed, the acid is destroyed and cyanuret of potassium remains, mixed with carbon and iron. If correctly done, the aqueous solution, leaving the carbon and iron, will be colorless, and will not precipitate prussian blue from an acid solution of a per salt of iron. The cyanuret of potassium is fusible, and when kept dry, is not liable to change.‡

Composition.—Cyanogen, 1 equiv. 26, + potassium, 1 equiv. 40 = 66, its equiv.

HYDRO-CYANATES,‡ (simple prussiates.||)

Salts formed between prussic acid and the bases.

1. The cyanuret of potassium can exist only in the dry state; when dissolved in water, it appropriates the elements of that fluid and forms hydro-cyanate of potassa.

The hydro-cyanates are formed also, by combining prussic acid (the hydro-cyanic,) with the bases.

2. Such compounds, with alkaline or other bases, were formerly called (for reasons that will soon appear,) *simple prussiates*; when with an alkaline base, the salt is always alkaline; soluble in water and alcohol; with salts of protoxide of iron gives an orange colored

* T. and Edin. Jour. Sci. No. xiii, p. 189.

† According to Dr. W. H. Ellet, it is when anhydrous, a compound of cyanuret of iron and cyanuret of potassium, Am. Jour. Vol. xviii, p. 329.

‡ These salts would have been introduced immediately after the prussic acid, had it not been that they are more intelligible in connexion with the ferro-cyanic acid and its salts.

§ Dissolve the pure bi-cyanide of mercury in pure water, and add a solution of hydro-sulphate of potash so long as a black precipitate falls, the clear liquor is a solution of hydro-cyanate of potassa.—A. A. HAYES. || Of the old nomenclature.

3. Composition.

(a.) It is a singular fact that *while all the elements of prussic acid are present in this acid, its properties are widely different*; this is supposed to be accounted for by the combination with metallic iron.*

(b.) *The elements are differently assorted by different writers*, and we are still without decisive evidence of their real arrangement.

(c.) According to Mr. Porrett, this acid is composed of 1 equiv. of hydro-cyanic acid 27, + 1 of iron 28, + 2 carbon 12 = 67.

Dr. W. H. Ellet, preferring the analysis of Robiquet,† as giving the nitrogen and carbon in the proportions in which they are known to exist in cyanogen, states its composition as being cyanogen 2 equiv. = 52, + 1 of iron 28, + 1 of hydrogen = 81, or giving 1 equiv. of the cyanogen to the iron, and 1 to the hydrogen, there will be cyanuret of iron 1 equiv. 54, + prussic acid 1 = 27 = 81 as before; or, since it resembles the hydracids, the cyanogen 2 equiv. 52, may all be given to the iron 28 = 80, which may be regarded as a base, and the 1 equiv. of hydrogen = 81, completes the acid.‡

M. Robiquet afterwards proposed a different arrangement, so as to admit of the existence of prussic acid and cyanuret of iron§—thus cyanogen 3 equiv. = 78, iron 1 = 28, hydrogen 2 = 108; assorted thus, = 2 equiv. of cyanogen 52 + 2 of hydrogen = 54, + 1 iron 28, and cyanogen 1, 26 = 54 = 108.

Upon this view the base of the acid is composed of 3 equiv. of cyanogen = 78, + 1 of iron 28 = 106, made acid by 2 of hydrogen = 108; or the base may be composed of cyanogen 2 equiv. = 52, + cyanuret of iron 2 = 54 = 106, and then 2 of hydrogen = 108.

It is obvious that the subject is by no means fully elucidated.||

The simple prussiates retain names indicating their composition, and are therefore called prussiates or hydro-cyanates, while ferro- is prefixed to the combinations of the acid in the triple prussiates, and when another substance, as for example sulphur, takes the place of the iron, the nomenclature is altered accordingly, as will presently appear.¶

* This is in accordance with Mr. Porrett's more mature opinion; at first he supposed that the iron was in the state of oxide.

† Ann. de Chim. et de Phys. Vol. xii.

‡ Am. Jour. Vol. xviii, p. 331.

§ Ann. de Chim. et de Phys. Vol. xvii, p. 197.

|| In the assortment of equivalents so as to bring out a desired result, severe as this mental exercise appears, there seems to be some room for the indulgence of the imagination; see Berzelius, Ann. de Chim. et de Phys. Vol. xv, p. 144, and Robiquet, Vol. xvii, p. 196.

¶ I do not think it necessary to mention the singular nomenclature proposed by Mr. Porrett, since it was never adopted by chemists.

When ferro-cyanic acid combines with the oxides of bases, it is supposed, at least when they are dried at a high temperature, to relinquish the hydrogen to the oxygen of the oxide, and thus the compound becomes a cyanuret of the base.

FERRO-PRUSSATE OR FERRO-CYANATE OF POTASSA.

1. Preparation.

(a.) *By digesting to saturation caustic potassa with purified prussian blue.*†

(b.) *In the arts, it is largely formed in the process for prussian blue, (p. 267, of this volume,) blood or other animal matter being calcined, probably with the addition of iron or its oxide.*

2. Properties.

(a.) *Obtained by evaporation, in neutral lemon yellow crystals, quadrangular tables derived from an acute rhomboid.*

(b.) *Inodorous, slightly bitter, does not change in the air; sp. g. 1.83; soluble at 60° in 3 parts of water, and in a little more than 1 at 212°.*

(c.) *By heat, it loses .13 of water, and becomes white, but without fusion; by ignition in close vessels, it is decomposed and yields prussic acid, carbonic acid and carbonic oxide, carburetted hydrogen and ammonia, and leaves charcoal with iron and alkali containing cyanogen.*‡

(d.) *Fuming muriatic acid evolves ferro-prussic acid, and forms a white precipitate; it is dissolved by sulphuric acid, and the diluted sulphuric and muriatic acids, and even acetic acid, with heat, evolve common prussic acid.*

(e.) *Not decomposed by alkalis or alkaline salts, whence, as well as from similar reasons already stated, it is inferred that its iron exists not in the base but in the acid.*

(f.) *Composition.—There is so much difference of opinion on this point, that I shall not enter upon a discussion of the evidence, but simply state results.*§

Dr. Turner gives the following as the most probable result—cyanogen 3 equiv. = 78, potassium 2 = 80, iron 1 = 28, hydrogen 3, oxygen 3 = 24 = 213.

* By digestion with 1 part sulphuric acid diluted with 6 of water to remove alumina.

† The pale simple prussiate becomes yellow ferro-prussiate by digestion with protoxide of iron, and the remaining unsaturated alkali may be neutralized by prussic acid.

‡ Robiquet, Ann. de Chim. et de Phys. Vol. xvii, p. 205.

§ See Phil. Mag. and Annals, Vol. i, p. 110, and Henry's Chem. Vol. ii, p. 374. 11th Ed.

Berzelius regards it as a double cyanuret of potassium and iron, and not as a prussiate; as a ferro-cyanate, it may be regarded as composed of ferro-cyanic acid 81, (composed of cyanogen 2 equiv. 52, + iron 1, 28, + 1 hydrogen,) with potassa 1 equiv. 48, and water one, 9=138; or as a double cyanuret, (the cyanogen being equally divided between the metals); of cyanuret of iron 54, (composed of 1 cyanogen 26 + 1 iron 28,) and cyanuret of potassium 66, (composed of cyanogen 26, + potassium 40) = 120. The difference, 18, between this and the preceding result, is made up of the oxygen in the potassa 8, + water 9, + 1 hydrogen in the acid.*

This salt is of great utility in the arts, for forming prussian blue, and in chemistry, for precipitating nearly all metallic† and some earthy salts.

There is nothing in the prussiates of the other alkalies and alkaline earths that requires detail; they are formed in the same manner with the salt just described, and some of them, particularly the prussiates of soda, ammonia, lime and baryta, are occasionally used as tests or to aid in forming some of the prussic preparations.

PRUSSIAN BLUE.

This compound has been briefly mentioned in the present volume, p. 267, and in Vol. I, p. 417. The theory of its formation and the actual state of the elements and principles, have been the subject of much experiment and discussion, and of great difference of opinion, from the period of Scheele's admirable investigation to this time.

It would be of little use to the general student as well as inconsistent with the limits of this work, to reiterate the numerous researches and various opinions of very able men upon the prussic compounds, and especially upon the parent substance, Prussian blue.‡ The most probable results are all that we can give.

1. We have already stated, that *the basis of the coloring principle of Prussian blue is generated by the reaction of the elements of the animal matter in the fire, and it appears that the compound is at first in the condition of cyanuret of potassium; that is to say, the cyanogen, the basis of prussic acid, unites with the potassium of the potassa.*

If there were no iron in the materials, the solution of this cyanuret in water would give simply a prussiate or hydro-cyanate of potassa;

* Dr. W. H. Ellet, in Am. Jour. Vol. xviii, p. 332.

† See a table, p. 611.

‡ They may be found in the Journals and other books of science, and in addition to those already cited, we may mention Scheele's Chemical Essays; Gay-Lussac, Ann. de Chimie, Vol. lxxxviii, p. 123; Proust, Id. Vol. ix, p. 225; Porrett and Robiquet, Ann. de Ch. et de Ph. Vol. i, p. 120, Id. Vol. xii, p. 372 and 378; Vauquelin, Id. Vol. ix, p. 118.

but if iron filings or oxide of iron have been added* with the other materials, then the compound would contain iron and would be a ferro-cyanate of potassa, the elements of water having afforded the oxygen to the potassium and the hydrogen to the cyanogen.

2. In the arts, the proto-sulphate of iron is always added to the alkaline solution; agreeably to the prevailing theory, the hydrogen of part of the prussic acid reduces some of the iron to the metallic state; this unites with the cyanogen to form a cynuret of iron, which, combining with the remainder of the hydro-cyanic acid, forms ferro-cyanic acid; or, as the French authors more consistently call it, the hydro-ferro-cyanic acid.

3. Prussian blue is essentially† a compound of this acid with oxide of iron, and as the green sulphate is used in the manufacture, the iron is in the first instance, in the state of protoxide; but it passes, at least in a great proportion, to the condition of per-oxide, and prussian blue always contains a ferro-cyanate of the per-oxide of iron, or a ferro-prussiate of iron. Both for brevity and for euphony, *Prussian blue* is the preferable name.

4. With respect to the state of oxidation of the iron, chemists are not all agreed; most of them consider the iron as a peroxide; Dr. Thomson and Prof. Berzelius admit two oxides, and Dr. W. H. Ellet states, from his own experiments, that if all the iron that is in the state of red oxide is separated by muriatic acid, the ferro-cyanic acid left will equal 72 per cent. of the entire salt, and that if all the iron which it contains is converted into peroxide by the nitric acid, "a quantity is obtained whose proportion to that separated from an equal portion by muriatic acid is as 5:2." He thinks also, that the color depends on water combined, for strong sulphuric acid renders prussian blue white and water restores the color. In prussian blue he finds the acid is in the proportion of 1.5 to 1 base, and he gives the following as the only constitution reconcilable with the facts. One equivalent ferro-cyanic acid, 121.5, (composed of 3 cyanogen, = 78 + 1.5 iron = 42 + 1.5 hydrogen,) + 1 equiv. peroxide of iron = 40 (composed of iron 28, + oxygen $1\frac{1}{2}$ equiv. = 12,) + 1 equiv. of water, 9, = 170.5, the equiv. of prussian blue.‡

Miscellaneous facts and remarks.—The principal properties of prussian blue have been mentioned under iron; it may be added in relation to its combustibility, that Dr. Hare, on heating it red hot for about a minute in a glass tube and then sealing it, finds that it forms a pyrophorus, which fires when the tube is opened.

Chlorine turns prussian blue green, and it becomes blue again by disoxygenizing substances, such as the sulphates, sulphurous acid, &c.

* Or possibly, the iron may be derived from vessels of that metal in which the calcination is often performed, or even, in a small degree, from the blood when that is used.

† See the qualifications to this opinion in the notes to p. 268 of this volume.

‡ Am. Jour. Vol. xviii, p. 331, Id. Vol. xix, p. 173.

Besides the alumina already mentioned, as being mixed with prussian blue, the manufacturers add often chalk, starch or plaster of Paris. Prussian blue has so powerful an attraction for water that it absorbs it rapidly from the atmosphere.

Gay-Lussac's first opinion, after the discovery of cyanogen, was that prussian blue is a cyanuret of iron. Berzelius,* denying the existence of ferro-cyanic acid, regarded it as a prussiate of both protoxide and peroxide of iron, in variable proportions. Robiquet viewed it as a cyanuret of iron combined with prussiate of peroxide and water. In Dr. Murray's Elements, the opinion is maintained that in ferro-prussic acid the iron is in the state of a base, and that in the triple prussiates the bases are united with super prussiate of protoxide of iron composed of 3 equiv. of prussic acid and 1 of protoxide of iron.

OTHER FERRO-PRUSSIATES AND CYANURETS.

The ferro-prussiates of other metallic bases are obtained by double exchange, between ferro-cyanate of potassa and the soluble salts of metals; thus, the ferro-prussiate of lead is white, and by a moderate heat it becomes a double cyanuret of iron and lead; when heated, it is converted into a pyrophorus and takes fire on coming to the air.

The same thing happens with the parallel compound, with copper, and also with cobalt; the prussiate of cobalt is deep green. The prussiate of mercury is formed by boiling peroxide of mercury with water, on prussian blue. The cyanuret of silver turns bluish by desiccation and becomes a pyrophorus like the rest.

Table of precipitates formed by ferro-cyanate of potassa in metallic solutions.—Thénard.

From solutions of salts of				Color of precipitate.
Iron, (protoxide,) - - -	-	-	-	white.
(deutoxide,) - - -	-	-	-	pale blue; peroxide, deep
Copper, (protoxide,) - - -	-	-	-	white. [blue.†
(deutoxide,) - - -	-	-	-	deep brown.
Platinum, - - -	-	-	-	yellow.
Palladium, - - -	-	-	-	olive.
Silver, - - -	-	-	-	white, changing to blue.
Nickel, - - -	-	-	-	apple green.
Cobalt, - - -	-	-	-	grass green.
Titanium, - - -	-	-	-	reddish brown.
Uranium, - - -	-	-	-	blood red.
Gold, Mercury, (deutoxide,) Lead, } Tin, Zinc, Manganese, Antimony, } Cadmium, Bismuth, Cerium, }				white.

* Ann. of Philos. N. S. Vol. i, p. 444.

† The color, so altered, has received different names, as Antwerp blue, fig blue, &c.

but if iron filings or oxide of iron have been added* with the other materials, then the compound would contain iron and would be a ferro-cyanate of potassa, the elements of water having afforded the oxygen to the potassium and the hydrogen to the cyanogen.

2. In the arts, the proto-sulphate of iron is always added to the alkaline solution; agreeably to the prevailing theory, the hydrogen of part of the prussic acid reduces some of the iron to the metallic state; this unites with the cyanogen to form a cyanuret of iron, which, combining with the remainder of the hydro-cyanic acid, forms ferro-cyanic acid; or, as the French authors more consistently call it, the hydro-ferro-cyanic acid.

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* Or possibly, the iron may be derived from vessels of that metal in which the calcination is often performed, or even, in a small degree, from the blood when that is used.

† See the qualifications to this opinion in the notes to p. 268 of this volume.

‡ Am. Jour. Vol. xviii, p. 334, Id. Vol. xix, p. 173.

Sulphuret of cyanogen.—Lassaigne,* by mixing per-chloride of sulphur 1 part with 2 of cyanide of mercury, and leaving them some days in a flask, has obtained a new compound of sulphur and cyanogen; it is a colorless crystalline sublimate, in rhomboidal scales, which powerfully decompose light. It is very volatile and pungent. Exposed to air and light, it soon becomes yellow. It dissolves, both in water and alcohol. Its solution in water reddens litmus, and gives a red color to the salts of iron. This is the only compound of these two elements which has hitherto been obtained in an isolated state. It contains 24 per cent. of sulphur, and may be considered as a di-sulphuret of cyanogen; we have therefore three known compounds of sulphur and cyanogen. 1st. 1 atom of sulphur + 2 atoms cyanogen. 2d. 2 atoms sulphur + 1 atom cyanogen. 3d. 4 atoms sulphur + 1 atom cyanogen.

The first is the sulphuret of cyanogen of Lassaigne. The second the base of the sulpho-cyanic acid of Porrett. The third is the base of the sulphuretted sulpho-cyanic acid of Berzelius, a yellow compound obtained by heating sulphur in prussic acid vapor.

Concluding Remarks.

The complicated and difficult subject of the prussic compounds appears to be much embarrassed by the existing nomenclature. Had the basis of prussic acid, (cyanogen,) according to an early suggestion of Sir H. Davy, obtained the name *prussine*, from its parent acid and salt, then the name of prussic acid would have been regularly derived from it; the cyanic acids might have been called oxy-prussic and oxy-prussous; the ferro-cyanic, (or, as the French have it, the hydro-ferro-cyanic,) would have been ferro-prussic, and so of sulpho-prussic and other similar acids; the cyanurets would have been prussides; the salts would have been prussiates, ferro-prussiates, oxy-prussiates, oxy-prussites, &c. and every thing would have harmonized with the original names and conception of the two parent bodies, prussian blue and prussic acid. Had it been foreseen, by its illustrious discoverer, that cyanogen is not, after all, what its name implies, probably the present terms would not have been introduced, and were they not so thoroughly inwrought into the very texture of the established language of all chemical authors, it would seem better, even now, to resort to a more simple and harmonious, and a more easily intelligible nomenclature.

Mr. A. A. Hayes, by distilling nitric acid 8 parts, (containing 1 of dry acid,) from 1 of raw sugar, returning the condensing fluid upon the sugar, and redistilling, filled a small room with the effluvia of prussic acid, so that the air became irrespirable, and the decanted fluid, mixed with ammonia, and then with proto-sulphate of iron and an acid, gave a bulky precipitate, which by exposure to the air, became prussian blue. *Am. Jour. Vol. xviii, p. 201.*

* Poggendorff's Annals, Vol. xiv, p. 532; quoted in *Am. Jour. Vol. xix, p. 378.*

APPENDIX TO ANIMAL SUBSTANCES.

A few topics remain which may be not inconveniently disposed under this head.

GASTRIC AND PANCREATIC FLUIDS.

Gastric juice.—*This is the immediate solvent* of the food of animals, and is secreted in the stomach.* Obtained from animals that have been killed after fasting† for some time; it is a transparent fluid, neither acid nor alkaline, but has a slightly saline and bitter taste; it precipitates nitrate of silver, and the residuum, after evaporation, is deliquescent and has an unpleasant odor.—H. During digestion it contains an acid; Dr. Prout‡ ascertained that it is generally the muriatic,§ and in severe cases of dyspepsia the acid is often thrown from the stomach in considerable quantity. Acetic acid is secreted, along with the muriatic, when the stomach is stimulated by food or by any foreign body, even by flint stones.|| In herbivorous animals phosphoric acid has been found.¶

The gastric fluid contains a little albumen, gelatin and mucus. *There is nothing in the nature of the chemical agents hitherto ascertained in this fluid, that will adequately explain its action in dissolving food, and thus preparing it for assimilation.*

It coagulates milk, probably by some power not dependent on acids. If the animal temperature is preserved, *it dissolves alimentary substances out of the stomach,** and dissolves and removes food from perforated silver balls or tubes introduced into the stomach, and leaves them empty.††*

A few years since, a soldier, whose stomach had been perforated by a wound which long remained open, permitted the surgeon of the post to convey into his stomach, through this opening, portions of different varieties of meats and other substances properly secured, and to withdraw them by a string at the end of particular periods; they were found in every stage of digestion, corresponding with all that has been here-

* If that can be called a solvent which decomposes the food and recomposes it into a new form, for neither chyme nor chyle consist of a solution of food, or even contain the same proximate principles.—W. R.

† It is obtained also from the human stomach, by voluntary vomiting before breakfast, and from fasting animals, by thrusting sponges attached to wires down their throats.

‡ Philosophical Transactions, 1824, p. 45.

§ Ascertained by Dr. Prout to exist also in the stomach of the rabbit, horse, calf and dog.

|| Tiedman and Gmelin, quoted by Dr. Turner.

¶ Vauquelin.

** It appears then, in no way extraordinary, that it should attack the stomach itself after death, as it is stated to do on the authority of John Hunter. This happens particularly with strong carnivorous animals, which, when examined a few hours after a sudden death, exhibit corrosion in the depending part of the stomach.—Murray.

†† Spallanzani, Reamur, Stevens.

tofore stated as to the solvent power of the gastric fluid.* *In this manner it is known that the chyme is prepared*, from which, in its passage through the smaller intestines, the nutritious matter is withdrawn by the proper vessels. *The gastric fluid is a powerful antiseptic*, and not only prevents putrefaction in aliment already received, but out of the body also, corrects incipient decomposition, and restores tainted meat to sweetness. The subject of digestion† belongs to animal physiology, and we therefore dismiss it with these few citations of facts. It is obvious that *we are not yet certain what the pure gastric fluid is*, for, even in fasting animals it is very liable to admixture with foreign substances. According to Chevreul, 98 parts in 100 are water.

Pancreatic juice.—*The saline contents of this fluid are similar to those of saliva*, which fluid it has been supposed to resemble. It does not contain the sulpho-cyanic acid. *It affords twice as much solid matter as saliva*, this matter is *principally albumen*‡ with some of the animal matter of saliva and a little osmazome. It reddens litmus paper, an effect attributed to acetic acid. The uses of the pancreatic fluid are unknown.

CALCULI.

URINARY CALCULI.—Omitting most of the medical topics connected with this subject, it is my purpose to present merely an outline of the composition, and of some of the leading properties of these bodies, abridged from the best authorities.§

Urinary calculi may be arranged according to the substances prevailing in their composition, under six species, this is the division of Dr. Henry; Fourcroy and Vauquelin formerly made twelve divisions. I. Uric acid or urate of ammonia; II. Phosphate of lime; III. Phosphate of ammonia and magnesia; IV. Carbonate of lime; V. Oxalate of lime; VI. Cystic oxide or animal oxide.

Among 600 calculi examined by Fourcroy and Vauquelin, those of uric acid constituted $\frac{1}{4}$; oxalate of lime $\frac{1}{5}$; uric acid and earthy phosphates in distinct layers, about $\frac{1}{12}$; the same but intimately mixed,

* I regret that I loaned and cannot recover the printed document forwarded to me by the surgeon of one of the forts on the great lakes where this case occurred, and that I cannot therefore, state more particulars, which may be found in the North Am. Med. Jour. of Philadelphia. I recollect that meats, prepared with simple cookery, were digested sooner and more perfectly than a-la-mode beef, and other similar articles prepared with stuffing, spices, &c., and raw cabbage was said to be dissolved sooner than any thing else. The man was wounded in the late war. and his wound did not prevent his performing light duties, the orifice being closed by a proper application.

† For the singular experience of Dr. Montègre, see Thénard's Chemistry, Vol. iv, p. 597, 5th edition.

‡ Gmelin and Teidman as quoted by most recent elementary works.

§ Dr. Henry's Chemistry, Phil. Trans. 1797, Dr. Wollaston, Dr. Marcet's Essay on calculous disorders, Phil. Trans. 1829, Ann de Chim. Vol. xxxvi, Prout, Dr. Pearson, Phil. Trans. 1798, Prof. Blande, Fourcroy and Vauquelin, Scheele.

$\frac{1}{8}$; urate of ammonia and the phosphates in distinct layers, about $\frac{1}{10}$; the same intimately mixed, about $\frac{1}{8}$; oxalate of lime and uric acid in distinct layers, about $\frac{1}{8}$; oxalate of lime, uric acid or urate of ammonia, and earthy phosphates, about $\frac{1}{8}$. A single specimen was found of silica mixed with some of the phosphates; the urate of ammonia was rare.—*Thénard*.

I. CALCULI composed chiefly of URIC ACID.

The most common species, half or more, that have been discovered being of this kind, although it is rare that they consist of uric acid only; they contain $\frac{1}{8}$ of uric acid with urea and albuminous matter.*

Physical characters.—*Surface smooth*, size from that of a bean to that of a large egg. *Color* brown or yellow or reddish; *form* flattened oval, but by friction of several they acquire other forms; *sp. gr.* between 1.276 and 1.786; average about 1.5; *longitudinal section*, exhibits a nucleus, firmer and more brilliant than the stone; *structure* lamellar and fibrous; the radii in concentric layers, and marked by slight shades of color; the former varieties admit of a polish in the section, and resembles wood.

Chemical characters.—For most of them and for various facts see uric acid.—*Only slightly soluble* in cold water or in muriatic acid; *not fusible*, exhale the odor of burnt horn, and when heated in a crucible, leave a coal equal in weight to $\frac{1}{4}$ th of the calculus; consumed before the blowpipe, and leave a white alkaline ash.

Urate of ammonia.—*Color* that of clay—*surface* smooth or tuberculated—*fracture* fine earthy, although it is formed in concentric layers; small and rare, but often mixed with the calculus of uric acid; its powder is soluble in boiling water, and during its solution in potassa it exhales ammonia, but does not give it up with a heat of 440° F.: dissolves in alkaline sub-carbonates which is not the fact with the uric calculi;† often contains muriate of ammonia.‡ It decrepitates or deflagrates before the blowpipe.

II. CALCULI composed chiefly of PHOSPHATE OF LIME.

Called from the prevailing constituent, bone earth calculus.

Physical characters.—*Color* pale brown; *surface* smooth as if polished; *in section*, appear in laminæ, which are easily separated; *internal*, color white, without lustre; friable, staining the hands, paper and cloth; one of these calculi broke under the forceps; never contains crystals; *powder*, harsh when rubbed.

Chemical characters.—Insoluble in potassa, but slowly dissolve in dilute nitric or muriatic acid, or in the acetic but not in the sulphuric,

* In 150 calculi, Mr. Brande found uric acid, and in 16 it was pure or nearly so; it was found in the greater number of 500, examined by Fourcroy and Vauquelin, and of 300, examined by Dr. Pearson, and all those examined by Scheele were composed of uric acid alone. Dr. Henry found 10 out of 26 to be of this sort, exclusive of the alternating kind.

† Dr. Prout.

‡ Phil. Trans. 1829, p. 71.

of sp. gr. 1.020; it is precipitated unchanged by alkalies. The evaporated muriatic solution yields crystals which unite at angles of 60° and 120° : when the acid has withdrawn the phosphate of lime, a gelatinous matter is left in the form of a membrane. Before the blowpipe, this calculus blackens and then bleaches, and in a high heat, it ultimately melts. It is rare to meet with a calculus of pure phosphate of lime.

III. CALCULI composed chiefly of PHOSPHATE OF AMMONIA AND MAGNESIA.

Physical characters.—Rarely pure,* and generally contain phosphate of lime, sometimes voided in the form of a white sand, composed of small shining crystals,† and often such crystals are found between the layers of other calculi, or on their outside; between the laminæ of this calculus the same sparkling crystals are frequent. It often forms alternating layers with phosphate of lime, and with uric acid, and sometimes it becomes a nucleus for the latter. Color white, generally very pure; friable between the fingers; the powder is sweetish.

Chemical characters.—Soluble in cold acetic acid, and still more so in the stronger acids, which, on the addition of ammonia, yield it again unchanged. Water at 212° dissolves $\frac{1}{15}$ of the calculus, and on cooling, the matter falls in shining crystals. Potassa and soda evolve ammonia but without dissolving the calculus. By the blowpipe it blackens, ammonia is exhaled and a white powder remains of very difficult fusion, unless there is also phosphate of lime present, when a small fragment readily melts, the two phosphates acting as fluxes to each other; it is called the *fusible calculus*, and weak acids dissolve out of it the phosphate of ammonia and magnesia, leaving the phosphate of lime, and thus an approximation is made to their proportions; if the uric acid is present, it will be left, and may be dissolved in a caustic alkali.

Miscellaneous remarks.—Calculi of this kind are frequent, and attain a greater size than those of uric acid; in one or two cases, they have been known even to fill the bladder.‡ The triple phosphate is readily deposited from putrescent urine, and from that which is healthy, when it touches a foreign body; hence drains for urine are often studded with its crystals, and it soon concretes around any extraneous body in the bladder, or on the inner coat of that organ, if diseased.

IV. CALCULI composed chiefly of CARBONATE OF LIME.

These are very rare; are small, white and friable, and the parts have been found cemented by animal mucus; in those cases they had nearly the color of the mulberry calculus.§

* Mr. Brande had some years since, seen but two that were pure; they were externally crystallized.

† It then forms the white gravel as uric acid does the red gravel.

‡ Phil. Trans. 1809, p. 303. § Dr. Henry quoting the Medico-Chir. Trans. xi. 14.

$\frac{1}{3}$; urate of ammonia and the phosphates in distinct layers, about $\frac{1}{3}$; the same intimately mixed, about $\frac{1}{3}$; oxalate of lime and uric acid in distinct layers, about $\frac{1}{3}$; oxalate of lime, uric acid or urate of ammonia, and earthy phosphates, about $\frac{1}{3}$. A single specimen was found of silica mixed with some of the phosphates; the urate of ammonia was rare.—*Thénard*.

I. CALCULI composed chiefly of URIC ACID.

The most common species, half or more, that have been discovered being of this kind, although it is rare that they consist of uric acid only; they contain $\frac{1}{8}$ of uric acid with urea and albuminous matter.*

Physical characters.—*Surface smooth*, size from that of a bean to that of a large egg. *Color brown or yellow or reddish*; *form* flattened oval, but by friction of several they acquire other forms; *sp. gr.* between 1.276 and 1.786; average about 1.5; *longitudinal section*, exhibits a nucleus, firmer and more brilliant than the stone; *structure* lamellar and fibrous; the radii in concentric layers, and marked by slight shades of color; the former varieties admit of a polish in the section, and resembles wood.

Chemical characters.—For most of them and for various facts see uric acid.—*Only slightly soluble in cold water* or in muriatic acid; *not fusible*, exhale the odor of burnt horn, and when heated in a crucible, leave a coal equal in weight to $\frac{1}{4}$ th of the calculus; consumed before the blowpipe, and leave a white alkaline ash.

Urate of ammonia.—*Color* that of clay—*surface* smooth or tuberculated—*fracture* fine earthy, although it is formed in concentric layers; small and rare, but often mixed with the calculus of uric acid; its powder is soluble in boiling water, and during its solution in potassa it exhales ammonia, but does not give it up with a heat of 440° F. : dissolves in alkaline sub-carbonates which is not the fact with the uric calculi;† often contains muriate of ammonia.‡ It decrepitates or deflagrates before the blowpipe.

II. CALCULI composed chiefly of PHOSPHATE OF LIME.

Called from the prevailing constituent, bone earth calculus.

Physical characters.—*Color* pale brown; *surface* smooth as if polished; *in section*, appear in laminæ, which are easily separated; internal, color white, without lustre; friable, staining the hands, paper and cloth; one of these calculi broke under the forceps; never contains crystals; *powder*, harsh when rubbed.

Chemical characters.—Insoluble in potassa, but slowly dissolve in dilute nitric or muriatic acid, or in the acetic but not in the sulphuric,

* In 150 calculi, Mr. Brande found uric acid, and in 16 it was pure or nearly so; it was found in the greater number of 500, examined by Fourcroy and Vauquelin, and of 300, examined by Dr. Pearson, and all those examined by Scheele were composed of uric acid alone. Dr. Henry found 10 out of 26 to be of this sort, exclusive of the alternating kind. † Dr. Prout. ‡ Phil. Trans. 1829, p. 74.

of sp. gr. 1.020; it is precipitated unchanged by alkalies. The evaporated muriatic solution yields crystals which unite at angles of 60° and 120° : when the acid has withdrawn the phosphate of lime, a gelatinous matter is left in the form of a membrane. Before the blowpipe, this calculus blackens and then bleaches, and in a high heat, it ultimately melts. It is rare to meet with a calculus of pure phosphate of lime.

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BILIARY AND SALIVARY CONCRETIONS.—It has already been stated, that biliary concretions consist principally of the peculiar fatty matter, called chloresterine and inspissated bile. In salivary concretions, as far as they have been examined, carbonate of lime prevails, with some phosphate of lime and animal matter, and occasionally with phosphate of magnesia.

SPONTANEOUS DECOMPOSITION.—PUTREFACTION.

1. *Of vegetable substances.*—The few remarks necessary to be made upon vegetable decomposition were reserved for this place, as the causes of both vegetable and animal decomposition are, in a considerable degree, similar. Minerals may, in some cases, suffer spontaneous decomposition, but they cannot undergo the putrefactive fermentation, and it happens to plants and animals only after they are deprived of life;* a certain degree of heat and moisture, aided generally by air, being the great agents in both cases; a temperature between 60° and 100° is the most favorable; at 32°, the process is entirely arrested, and it does not commence, if the organic bodies are in a state of perfect desiccation.

Vegetables rarely undergo a decomposition strictly putrefactive; the azotized vegetables are, of course, excepted from this remark; for, as has been several times observed, they putrefy with animal effluvia, and form products very similar to those of animal bodies. When they are not azotized, they are however, under favorable circumstances, spontaneously decomposed, and the process is most apt to commence and proceed when they are accumulated in a moist state. If immersed in water or otherwise secluded from the air, the gas exhaled is chiefly carburetted hydrogen; if the air has access, carbonic acid is more abundantly produced; those vegetable substances in which the oxygen and hydrogen are in the proportions to form water, are particularly prone to decomposition; those in which oxygen prevails, as the acids, and those in which carbon and hydrogen are predominant, as the resins, oils and alcohol do not putrefy. The odor of putrefying or decomposing vegetables, especially when in large quantity, is offensive and doubtless noxious, although we cannot designate with precision, the immediate agent in any of the varieties of malaria. The ultimate decomposition of vegetables exhales into the air most of the hydrogenous portions, and no small share of the oxygen and carbon assume an aerial state and passes off in gas or vapor; the carbon lingers longer than either of the other vegetable elements, and mingling with the soil, contributes to form the dark vegetable mould from which however it may, by constant access of oxy-

* A particular part, as is well known, may suffer this change, in a greater or less degree, without being severed from its natural connexion.

gen in the air, aided by a proper temperature, escape in the form of carbonic acid or oxide, and ultimately nothing of the plants may remain in the soil except the fixed alkalies, the earths and the metals. We do not here advert to those peculiar geological circumstances in which, under the pressure of superincumbent masses, and in seclusion from the air, accumulated vegetables may be so decomposed and modified, as to retain most of their principles, and to assume, in one case, the form of lignite, and in another, that of coal and other varieties of bituminous matter. It is unnecessary to enlarge farther upon this topic, most parts of which are foreign from the object of this work.

2. *Of animal substances.*—In the remarks introductory to animal substances, and in the history of their proximate principles, nearly every thing important, in relation to this subject, has been already stated. Animal bodies are in general extremely prone to putrefaction, and although this change will happen without air, it is accelerated by its presence.

It is scarcely necessary to name the insupportable odor of the aerial exhalations from animal putrefaction, and which, although in general less noxious to health than the less obvious effluvia of vegetables, are sometimes instantly fatal, especially when concentrated.* Chlorine is however a perfect antidote, provided it is seasonably and properly applied.

The preservation of organic, and especially of animal matter, by smoke, by salts, acids, alcohol, and sugar, has been attributed to their abstracting water, and although this is probably only a part of their agency, that theory derives support from the fact that animal substances, in perfect desiccation, do not suffer any change for years, and sometimes for centuries. Mummies, although filled with antiseptics, are also made very dry, and are kept secluded from the air; bodies are preserved in the dry sands of Africa; and in some earths, on account of their natural saline impregnations, the corpses do not putrefy; this is the fact in some peat mosses, owing to the antiseptic properties of the fluids.† Cold alone is an absolute preventive of animal putrefaction; it does not begin, at the freezing temperature, even after ages have passed, as is sufficiently evident from the perfectly sound condition of the frozen elephant and rhinoceros, found in the ice in the high banks of Siberia, near the northern ocean, where they must have been deposited when the country, after being first deluged, was immediately after subjected to the rigors of an arctic winter.

* As happened to some of the persons concerned in removing the dead bodies from the burial ground of the Innocents at Paris, and the like fatal result has too often attended the cleansing of the sewers of the same city, the effluvia from which may be presumed to have been chiefly animal.

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Animal as well as vegetable putrefaction causes the dissipation of a large part of the matter in aerial forms, and the remainder, containing the more fixed parts,* crumbles down and mingles with the soil. Thus both plants and animal either return to the bosom of the earth and the waters, or mingle with the atmosphere; and in both these modes they are prepared again to afford their elements, either as materials or as food to new races of organized beings, destined by the unalterable laws of the creator, to travel anew the same round of renovation and destruction.

GALVANISM.

Remarks.—This science treats of various and highly interesting phenomena produced by certain arrangements, connexions and reactions of matter, and now designated by the word Galvanism, in honor of Prof. Galvani, who, by observing certain muscular contractions,† produced by electric excitement, laid the foundations of the science. Electricity, heat, light, and magnetism, are more or less concerned, and most of the facts necessary to render the subject of Galvanism intelligible have been either premised in the present work, or are well known. In accordance however, with the custom of authors, a few leading facts and principles in relation to electricity may be advantageously stated; by way of introduction to that which constitutes more appropriately the province of Galvanism.

ELECTRICITY as connected with GALVANISM.

*Electricity is a power or an influence, every where diffused, and which exists apparently in all bodies; it is imponderable; invisible except when excited; like light and caloric, it is self repellent; it also endows other bodies with attraction, and with apparent repulsion; its materiality is not proved, but is generally admitted; its name is derived from the Greek *ηλεκτρον*, (amber,) by the friction of which it was evolved by the ancients. It was noticed by Theophrastus, A. C. 300, by whom the *lyncurium*, supposed to be the tourmalin, is also named as attracting light bodies. No farther mention of electricity is found until it is noticed again in 1600, by Wm. Gilbert, an English physician, in his treatise *de magnete*. He discovered that several other bodies may be rendered magnetical, and a number of electrical experiments are described in his work.*

* The proper osseous part of the animal skeleton, being in its composition assimilated to mineral matter, is often very permanent, and, especially in the larger and firmer animals, it remains long unchanged even in sepulture; when dried and secluded from injury, bones are as permanent as many minerals. This is the fact particularly when they are imbedded in the rocky strata, and where, whether mineralized or not, they are thus preserved from the influence of external agents.

† See a more particular notice of the fact, p. 631.

plate is used to touch the zinc plate, there is no effect, which prove, that it is owing to diversity. He has found also that twelve plates of copper alternating with twelve of zinc, and divided into pairs by pieces of paper, will affect a single leaf electrometer.

(b.) Zinc, iron, tin, lead, copper, silver, gold, platinum and charcoal, are electrified by contact, so that, in each instance, the preceding body is positive, with respect to the succeeding, which is negative.

(c.) Zinc filings poured through holes in a copper plate are made positive, and falling on a common electrometer affect it; copper filings produce a similar effect.

(d.) Crystals of dry oxalic acid, touched by quick lime, become negative, and the lime positive. The acid crystals, by contact with a plate of metal, generally render it positive. Acids are negative with respect to alkalies, metals, and earths, as may be evinced by contact. Metals are positive with respect to acids.

(e.) Bodies which show electrical effects immediately after contact, lose this power by combination; thus polished zinc by contact with dry mercury, becomes positive, but ceases to be electrical after being heated so as to combine; the same is the fact with copper and sulphur.—*Davy*.

1. *Non-electrics or Conductors of Electricity.*

1. *All the known metals*; the best conductors among the metals, are copper, silver, gold, and iron, but all of them have a conducting power vastly greater than that of water.

Well burnt charcoal, whether solid or in powder, soot and lamp-black; plumbago; concentrated acids; diluted acids and saline fluids; metallic oxides and ores; animal fluids; water; ice and snow, above -13° F.; living vegetables and animals; flame, smoke, steam, vapor and humid gases; most saline substances; rarefied air; most earths and stones.

2. Some of the above substances are found either among conductors or non-conductors, as they are moist or dry; and the conducting power of some of them varies with the temperature; thus, hot water and hot charcoal conduct better than cold.

Electrics or Non-conductors.

1. Shell lac, amber, and resins generally; lycopodium; sulphur, wax, jet; camphor, elastic gum; glass, and all vitrifications; talc; diamond, and all transparent gems; silk, whether raw, bleached or dyed; wool, hair, feathers; dry paper, parchment, leather; air, and all dry gases; baked wood, dry vegetable substances; porcelain, dry marble; massive minerals, not metallic; dry chalk, lime, phosphorus;

ice,* at -13° of F. ; many transparent crystals, when perfectly dry; ashes of animal and vegetable bodies ; oils, the heaviest apparently the best ; dry metallic oxides.

2. *Moisture turns the most perfect non-conductors into conductors.*

3. Resins, raw silk and Muscovy talc, (mica,) are least prone to attract moisture ; glass is moistened only superficially, and this is prevented by covering it with varnish or sealing wax.

4. *Heat causes many non-conductors to become conductors*, as glass, resin, wax ; the hottest air does not conduct, unless there is flame with it.

5. Paper, flannel, parchment, leather, and other porous and fibrous substances, must be dried or they are not electric.

6. Moist wood conducts, baked wood does not ; charcoal does, but the ashes and gases formed from its combustion do not.

ELECTRIC POLARITY—KINDS OF ELECTRICITY—MODES OF MEASURING BOTH KIND AND DEGREE.

1. *Attraction is the most striking power shown by electrified bodies.*

2. Either excited glass, or excited sealing wax or other resin, will separately, attract light bodies, as down, cotton and silk fibres, or a suspended pith ball or cork ; but apparent repulsion immediately follows, and attraction will not be renewed until the body has been again touched by a conductor ; the cork, for instance, in the state in which it was repelled by the glass, is attracted by the sealing wax ; and in the state in which it is repelled by the sealing wax, it is attracted by the glass, and so of the other bodies.

3. *These phenomena, on the hypothesis of Du Fay, have been imputed to two distinct kinds of electricity, called the vitreous and the resinous*, and this view is generally adopted on the continent of Europe, while that of *Dr. Franklin*, which attributed the appearance to one fluid, in the form of what he called *positive and negative electricity*, that is to say, an alternate accumulation and deficiency of this power, has been more generally received in Britain and in the United States ; of late, however, the theory of two electricities appears to be gaining ground in Britain and in America. It is not necessary to discuss the merits of either in this place. *The Franklinian hypothesis is the most simple*, and the terms positive and negative are so easily translated into the correspondent ones, vitreous and resinous, of the other theory, that *Dr. Thomson*, in his late work on heat and electricity, adopts the Franklinian terms, although he prefers the other hypothe-

* At which temperature electric sparks are said to have been obtained from it by friction.

sis.* I shall use the Franklinian terms and explanations, and leave the reader to choose his own hypothesis.

4. *When bodies are electrically excited, the two states of positive and negative electricity are always co-existent, either in the same or in contiguous bodies.*

5. *Various instruments have been invented to measure both the kind and degree of electric excitement.*

6. The most common is the gold leaf electrometer and the quadrant electrometer, but two straws or fibres of almost any kind, or two pith balls, will answer every common purpose; *they all operate upon the principle that bodies similarly electrified repel, and differently electrified, attract each other.* Here, as well as in the early part of this work, (Vol. I, p. 138,) the word repulsion is used as it is generally received, although it is maintained that the phenomena may be solved as well by the admission of attraction alone,† either for the ambient air or for other bodies, for even a vacuum is surrounded by matter, from and towards which an attraction may be exerted.

7. Condensing electrometers have been invented, for measuring very small quantities of electricity, and the torsion balance of Mr. Coulomb is extremely sensitive.‡

8. *The leaves of an electrometer, which have been made to diverge by excited sealing wax, will collapse if excited glass be applied; if both are applied at once, and their energy is equal, no effect will be produced.*

9. Excited glass is usually positive, excited sealing wax is negative; those bodies therefore which, when excited, cause the leaves which have diverged from the contact of excited glass to diverge more, are positive; if to collapse, negative, and vice versa.

10. Warm and dry flannel, in a roll, rubbed over sealing wax, will cause the leaves of the electrometer to diverge; if the sealing wax be then applied, they will collapse; the flannel therefore was positive and the wax negative; if applied both at once, in their excited state, no effect is produced.

11. *The same substance may be rendered positive or negative by friction with different bodies;* polished glass, by friction with silk, skin, wool, or metal, is positive, but the back of a living cat renders it negative, and is the only substance known to produce that effect.

12. The divergent leaves of an electrometer will continue divergent, if the cap be touched with a non-conductor in its natural state; if with a conductor, they will collapse.

* See Dr. Hare's discussion of the two theories, Am. Jour. Vol. vii, p. 103.

† Those who wish to see the arguments for the contrary opinion, can consult Dr. Thomson's late work on Heat and Electricity, chap. vi, p. 423.

‡ See the books on Electricity, particularly that of Dr. Thomson.

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CHEMICAL EFFECTS OF ELECTRICITY.

It does not appear to produce much heat in passing through very perfect conductors, of such a size that it is not accumulated in them.

But when the ball of a thermometer was placed in an electrical stream, whether in the air or in vacuo, the mercury rose 80° or 100° of F.* So, a similar effect follows when the electric spark passes between two oppositely electrified balls of wood.

A concentrated charge, with a proper arrangement, will also set fire to ether, alcohol, gunpowder, fulminating metals, resin, phosphorus, &c.

FUSION AND COMBUSTION OF METALS, &c.

1. *Leaves and wires of the metals are ignited, melted and dissipated* in globules or in smoke, arising from the actual combustion or minute division of the metal.

A jar of 190 square inches of coated surface, if properly managed, will fuse eight inches of watch pendulum wire. Cuthbertson's batteries of 15 jars will fuse 60 inches of iron wire of $\frac{1}{16}$ of an inch in diameter, and Mr. Singer melted 18 feet of this wire, at once, with 40 feet of surface.

2. The fusion of wire is even a test of the quantity of electricity; for a given quantity of this power, whether concentrated in a smaller or extended over a larger coated surface, will fuse the same quantity of wire.

Van Marum, with the highest charge of a battery of 135 square feet, melted 180 inches of iron wire of $\frac{1}{16}$ th of an inch in diameter, or 6 inches of wire $\frac{1}{4}$ th of an inch in diameter; 350 feet of coated surface melted 25 inches of the latter wire, and 550 feet melted 24 inches of it; it also rounded and partially fused quartz.

3. *Metals are not fusible by electricity in precisely the same order in which they melt in common fires*; for, taking wires of the same diameter, a particular quantity of electricity melted $\frac{1}{4}$ of an inch of silver and copper, $3\frac{1}{2}$ of gold, of iron 5, and of lead and zinc 120.

4. By powerful discharges also, metals are actually burned, and their oxides may be made to stain glass, paper, silk,† &c. Fine wires, stretched over paper or lying between its folds, will in this manner, stain it very beautifully.‡

5. *Electricity decomposes metallic oxides*, reviving the metals and disengaging the oxygen; it also disengages mercury from cinnabar.

* Murray, quoting Phil. Mag. Vol. viii, p. 198.

† See Singer, p. 175.

‡ See the plates in Wilkinson's Galvanism.

ELECTRIC LIGHT.

1. *This is often vivid; in condensed air and in dense gases, such as carbonic acid, it is white and brilliant; in rarefied air, it is divided and faint, and if highly rarefied, dilute red or purple.*

2. By means of an iron wire sealed into the top of a barometer tube, pass the electric spark through etherial or aqueous vapor formed in the Torricellian vacuum; a spark which, in the open air, would not exceed $\frac{1}{4}$ of an inch, will occupy 6 inches; when strong, it will usually be of a beautiful green.* A good vacuum is entirely illuminated by electricity.

3. *All the colors are seen if the electric spark is viewed through a prism, and various bodies are rendered phosphorescent with different colors; others are made transparent, as the thumb, clay, pumice stone, an egg, &c.*

4. The sparks, passing between two large balls from a powerful machine, will illuminate a large room, so that all the objects may be distinctly seen.

5. *Electricity passes from a positively electrified point in a brush of rays, and is received on a negatively electrified one in a luminous point.*

ACCUMULATION OF ELECTRICITY.

1. *This is effected chiefly by the Leyden Phial, and the battery, which is only a repetition of Leyden Phials; also by the electrophorus, the condenser and even the common exciting machine.†*

2. The principle, in all these cases is, that in proportion as electricity is accumulated in one part, it recedes from a contiguous part or a contiguous body, and the discharge is the restoration of the equilibrium.

MECHANICAL EFFECTS.

Whether electricity is a material agent or not, it produces the mechanical effects of an elastic fluid.

Discharges of it perforate paper, glass, &c.; break brittle bodies, as glass and stones, split fibrous ones as wood, and give sparks under water and various other fluids, &c.

ATMOSPHERICAL PHENOMENA.

All that belongs to the mutual relations of the electricity of the atmosphere and of the earth, producing thunder and lightning, and as some have supposed, water spouts, aurora borealis, australis, and other meteoric phenomena, is foreign to our subject.

* Singer, p. 96.

† For the description of these, see Cavallo, Singer, Thomson, &c.

ORIGINAL OBSERVATIONS AND FACTS, relating to the rise and progress of GALVANISM.

1. Sultz, a German, in 1767,* mentions, that if two different metals, as lead and silver, are brought into contact over the end of the tongue, there will be a peculiar sensation, which is not observed if the metals are applied separately; this experiment is best performed with silver and zinc; one of the pieces may be held between the upper lip and the front teeth, and the other laid beneath the tongue and projecting over the under teeth; thus they are easily brought into contact and separated, and at each contact the taste is perceived, and with many persons also, a mild flash of light.

2. Dr. Cotugno, of Naples, in March 1784, having, for the purpose of dissection, pierced a living mouse with his knife, the animal was convulsed and the doctor felt a shock through the left arm, with pain in the muscles as far as the neck, and internal tremor and giddiness; the arm was affected for 15 minutes.†

3. *The signal observation of Prof. Galvani*, which has perpetuated his name in connexion with an interesting branch of science, *was made in 1790 and published in 1791*. Some frogs, skinned for a soup, for his lady an invalid, lying near an electrical machine, a person by chance touched some of the internal nerves, at the time when a spark was drawn from the prime conductor, and convulsions then occurred in the frog, and were renewed at every repetition of the experiment, but not when a knife touched the nerves and no spark was drawn.

4. A frog, having a silver probe sticking in it, being suspended, by Galvani, from an iron palisado, was convulsed whenever the wind brought the silver into contact with the iron of the fence; but remained motionless when the steel scissors or forceps formed the medium of communication.

ELECTRICAL FISHES.

These convulsive movements in frogs, naturally renewed the interest in the electrical fishes.

The *Torpedo* was known to the ancients; the *Conger eel*, or *Surinam eel*, (*Gymnotus electricus*), was discovered about half a century ago;‡ more recently the *Silurus electricus* has been found in the rivers of Africa. The electric fishes have each an organ for giving a shock, and a smooth spotted skin, without scales.—*Cavallo*.

I. (a.) *The Torpedo*, (so called from the torpor produced by his shock,) is a flat fish, of the order of Rays, seldom twenty inches long, weighing only a few pounds and not uncommon on the coasts of Europe.

* In a work entitled "The General Theory of Pleasures." † Cavallo's Electricity.

‡ Or, as Singer observes, towards the close of the seventeenth century.

(b.) *The electric organs are near the head, and occupy the entire thickness and about one third of the length of the fish; they consist of polygonal columns of thin membrane, filled with a fluid and with large nerves; there are, in one organ, from 400 to 1200 columns, which are divided, by horizontal partitions, into 150 distinct parts, so that 4000 square inches or about 28 feet of surface are exposed. These organs are a natural galvanic or electrical apparatus.*

(c.) *Fifty shocks have been received from the torpedo in a minute; the strongest with the hands on opposite sides of the organs; none at all when on the same side and over them, and if only one hand is over them a feeble shock. The shock is strongest out of the water, and is not prevented by insulation of the fish; it passes through several persons, but is weakened.*

(d.) *The shocks obey the animal's will; at each effort the eyes are flattened, indicating the attempt to give the shock, even through non-conductors.*

II. *Gymnotus electricus*.*

(a.) *The Gymnotus is usually about three feet long; very thick, with a flat head and looking like an ill shaped eel, although it has no specific characters like that animal. It is sometimes eighteen feet long and of sufficient power to kill a man by its shock. Humboldt relates that horses driven into the water among these fishes, were dreadfully convulsed by them.*

(b.) *The electric organs are similar to those of the torpedo, but more simple; still the shock is much more powerful, and if the hands are applied near the head and tail, the shock will sometimes pervade the breast; if touched with one hand a tremor is felt.*

(c.) *The shock depends on the will of the animal, and is strongest when he is provoked; he easily stuns and kills small fishes.*

(d.) *The torpedo gives no spark; the Gymnotus produces a small but vivid one; his electricity passes through any good conductors, and even by the links of a chain, provided they are stretched.*

III. *Silurus electricus*.—His body is oblong, like those above named, smooth and without scales; *the electric organ seems to be towards the tail; it is said to give a shock, but very little is known of this fish.*

A fourth electrical fish was found on the coast of one of the Comoro Islands, S. lat. $12^{\circ} 13'$; it was seven inches long, two and a half broad, with a long projecting mouth, and seemed to belong to the genus *Tetrodon*; it gives strong shocks, and several persons have felt it at once.† There is a fifth electrical fish in the Indian seas; it is called *Trichiurus electricus*.

* A number of them, caught in the Surinam river, were brought to England, some years ago, and examined by Mr. Walsh.

† Cavallo, Vol. iii, p. 5, Electricity. Cats and rats are said occasionally to have given electrical shocks. If there was no mistake in the case of Dr. Cotugno, at Naples, already mentioned, the fact would not appear to be improbable.

MUSCULAR CONTRACTIONS OF ANIMALS, *observed before the invention of the pile.*

Remarks.—During about ten years, from 1790 to 1800, the attention of the philosophical world was intensely fixed upon this subject; for, the galvanic power was regarded by many persons, as an attribute of animal life; the muscle and nerve were supposed to be in opposite electrical states, and the convulsions to be produced by the discharge that restored the equilibrium; physiologists sought in these phenomena the cause of the nervous energy; of muscular movement and of animal functions; if not of animal life itself, and experiments on animals were therefore greatly multiplied. They have long since lost the high interest, which they possessed when associated with such views, and have indeed almost passed into oblivion.

I have however, thought it both useful and interesting, especially in relation to the pupils in science of the present day, to present some general notice of these remarkable phenomena, although they are now justly regarded as the results, chiefly, of electrical influence, and as proving that the animal body is a most delicate instrument, by which to discover and appreciate minute portions of this power, and of the other inponderable influences now collectively called galvanic.

Muscular contractions, &c. as observed by Galvani and others.

1. *Prepared frogs are very sensible* electroscopes, being convulsed when immersed in an electrified atmosphere, (e. g. near an electrical machine in motion,) and that whether they directly receive the spark or not. Insulated animals are agitated by very minute quantities of excited electricity. As animals with cold blood retain their excitability longer than those with warm, frogs, being peculiarly sensible and easily obtained, have been the most common victims of these experiments.

2. *Preparation of the frog.*—On removing the viscera, the crural nerves are exposed; the animal is easily flayed; those muscles only which we wish to touch are skinned; the frog is usually divided just under the arms; the lumbar portion of the spine is removed, leaving the upper part attached by the nerves alone to the lower extremities.

3. *The prepared frog being connected with a conductor of lightning in a thunder storm, was affected by the flashes as by artificial sparks;* and by rumbling thunder with a continued tremor.

4. *The contractions may be produced without any artificial or atmospherical influence;* as when, from the spine coated with tinfoil, an arc of silver touches a muscle; or if the nerve touches zinc and the muscle gold, and any conductor completes the circuit.

5. *If the nerve and muscle are joined by a single metal, contractions rarely ensue, and only in vigorous animals, recently killed:*† still it is said, that the legs of a frog being in mercury, and the nerves being made to touch the same metal, convulsions will follow at every contact.

Metals, the most remote in chemical character, are the most efficient; silver or gold, with zinc, tin, or copper, are good combinations.

6. Either in air or water, a live frog, with tinfoil on his back standing on a plate of zinc, is convulsed, when the zinc and tin are connected by a wire; the same happens with a flounder having a silver coin on his back. If the prepared frog hangs by one leg, and when the tin-coated spine touches the other, a silver coin is interposed, the hanging leg will vibrate powerfully.‡

Place the legs of a frog on zinc and the nerves on silver; join them by a wire, and the spasms will follow; and the same, if when a frog is made to connect a glass of water and a silver vessel of dilute acid, the connexion is completed by a metal.

7. Under similar circumstances, *contractions occur in nearly all animals, large and small, strong and feeble, and even in those apparently without nerves.*§ Place a dollar on zinc and a leech or worm on the dollar; it will be quiet while touching the silver only, but, if it touch the zinc, it recoils as from pain.||

8. *Chains of communication.*—Let several persons with clean and moist hands form a chain by firm grasping; let the first hold silver in one hand, and in the other the feet of a frog; let the second hold the nerves; and let the last person, with a piece of zinc touch the silver, and the frog will be convulsed, at every contact. While the vitality is still strong, the circuit may be completed by water, by different persons, and even by the materials of a room.¶

9. *Contractions are much more prone to take place in living animals if the skin is wounded* and tinfoil applied, and the human body or its recently amputated limbs, as well as those of animals, have been agitated in this manner.

10. *The heart, if placed between two metals*, as zinc and antimony, a communication being duly established, *contracts* and is said to be the only involuntary muscle which can be thus excited.

* Contractions have ensued by jarring the table and by bringing the scissors near two frogs; when they were insulated the effect ceased.—*Cavallo, Vol. II, p. 28.*

† That which contains the legs.

‡ Singer.

§ Some worms and insects, the oyster, and a few other small sea animals, are the only exceptions hitherto observed.

|| Singer. Dr. Hare tried this experiment unsuccessfully with a fine leech.

¶ Impurity in a single metal, will often cause it to produce the effects of two. Exhausted excitability is renewed by electrization, by chlorine, and by moving the armature, especially, nearer to the muscle.

11. *Fishes are very excitable*, especially when wet with alkali or chlorine; eels and tenches can scarcely be kept on the table.*

12. *The peristaltic motion is increased by galvanism*, and by a communication between zinc and silver properly placed on different parts of the body, has been known to produce correspondent effects.

13. *Muscular contractions have been excited without the intervention of any metallic matter*—as by a circle formed between the tendons, muscles, and blood of the frog.†

In a prepared frog, wet with salt water, and held by a foot, so that the nerves touch the muscles, contractions ensue; the same when the nerves of the frog are made to touch the tongue of the experimenter; the same when the frog is held on a glass rod, and the leg, by another glass rod, is brought into contact with the nerves.

In the detached thighs of several frogs, Humboldt brought on very powerful convulsions, by forming the connexion between the muscles and the crural nerves, by a small portion of muscle or of the nerve itself. These facts, besides being, in themselves, very curious, derive an additional interest from the connexion which they imply between physiology and galvanism.

EFFECTS of metallic contact ON LIVING BEINGS, in producing sensation, motion, &c.

1. *Vigorous animals, on their guard, can partially control the voluntary muscles*, unless the metals are applied to parts made very sensible by a wound or a sore, and the application of the metals will also renew motion, in parts rendered torpid by opium.||

2. *Sight and taste may be affected by metallic contact.*

(a.) The sensation produced by zinc and silver, under and above the tongue, has already been mentioned; a flash is perceived by many persons; it is stronger in some than in others, and it occurs, whether it be light or dark, and whether the eyes be open or shut.

(b.) Zinc within one cheek, being connected with silver within the other, a flash, and a peculiar taste, will be perceived, and sometimes a twitch.

(c.) Tinfoil on the ball of the eye, under the lid, and silver in the mouth, will, by due connexion, produce a faint flash, especially if the eyes are inflamed.§

* Wilkinson, Vol. i, p. 291.

† Volta.

|| Cavallo, Vol. iii, p. 51.

§ A similar connexion between the ear or the nose, sometimes draws drops of blood.

(d.) The taste, and often the flash are perceived, even when the connexion is formed between the nostrils, the ear, and other sensible parts and the tongue.

(e.) *Soldered seams of metals may be discovered by the taste*, when they escape the eye. Dr. Robinson could thus, by the tongue, detect the adulterations in gold and silver trinkets.

(f.) Connect two glasses of water by tin and silver, and when the tongue touches the one, apply a finger to the other, and a peculiar taste will be perceived.

(g.) Water in tin or zinc, standing on silver is tasteless, until the tongue touching the water, the hand grasps the silver, when taste is perceived.

(h.) Porter, cider, beer, wine, &c. or perhaps even water, drunk out of a metallic vessel, especially an alloy like pewter, gives a peculiar taste not perceived in porcelain or glass;* the liquor, the metal, and the saliva, form a galvanic circle, and the taste is owing to an electric movement.

Attempts to restore life.

All efforts to restore life by galvanism have been unsuccessful. A linnet which had just closed its eyes, and was insensible to a pin thrust into the body, was aroused by a proper connexion between a piece of zinc in the bill, and of silver at the vent; it now opened its eyes, stood erect, fluttered its wings, and breathed six or eight minutes, when it tranquilly expired.†

MISCELLANEOUS FACTS *depending on galvanic influence.*

(a.) Metallic vessels tarnish soonest at the soldered joints.

(b.) The copper sheathing of ships cannot be permanently secured by iron bolts, or by any metal more oxidable than the copper, because, whenever two different metals are connected with each other and with a saline water, a galvanic circle is formed, and the metals are more rapidly corroded.

(c.) The lead on which the Etruscan inscriptions were engraved, has been preserved to the present time, while more recent medals, formed of alloys, are much corroded.‡

(d.) The discoloration of a silver spoon in eating an egg is considered as a galvanic effect; a circle being formed by the spoon and the peculiar substances of the egg, of which sulphur is one. A simi-

* Porter drinkers have long made this distinction.

† As these statements are intentionally confined to animal excitement produced by the simplest means, and before the discovery of the pile and the battery, I do not now advert to the violent convulsions produced by those powerful instruments upon large animals recently killed, and upon executed criminals.

‡ Singer, p. 309.

lar effect is observed with mustard, and may perhaps depend upon a similar cause.

(e.) Zinc, in water, exposed to the air, is slowly oxidized, but much more rapidly if brought into contact with silver. Iron and silver in dilute muriatic acid, or zinc and silver in dilute sulphuric, are dissolved with increased rapidity, if in contact.

INVENTION AND CONSTRUCTION OF THE PILE *and of other varieties of galvanic apparatus.*

Professor Volta, of Pavia, is the undisputed discoverer of the pile, without which, and the various instruments that have been in consequence invented, galvanism would have turned to little account. Viewing the phenomena as having no necessary connexion with animal life and as arising from electricity, set in motion by the contact of different substances, Volta detached galvanism from all connexion with animals, and in 1800* communicated to Sir Joseph Banks his grand discovery of the Voltaic pile, as, in honor of the discoverer, it has been justly called. Regarding electricity and galvanism as the same thing, he divided the conductors of it into two classes, perfect and imperfect.

1. *Perfect*; including metals, some native metallic combinations, plumbago and charcoal.†

2. *Imperfect*; water, saline and acid solutions, animal fluids and fluids generally, and even fibrous solids, when moist.

3. "If, (says Volta,) in a series of three conductors, which touch two and two, we place either a conductor of the second class between two different ones of the first, or one of the first class between two different ones of the second, or finally, if we form a circle of three different conductors of the second class, without the intervention of any of those of the first—in these three cases, a current of electricity will be established, passing to the one extremity or the other, according to the predominating force of the substances arranged, which

* See Phil. Trans. for that year.

† Common charcoal, although it conducts the ordinary electricity, is unfit for galvanic experiments. It should be heated intensely, under sand, in a crucible placed in a forge or other furnace; or it may be formed from *lignum vitæ*, box wood, mahogany, sugar maple, or other hard wood, by igniting pieces of the proper size and shape, as above, but they are prone to crack and warp, and I have found it preferable to select good fine grained charcoal, (maple is the best,) and after sawing and filing the pieces to bring them nearly to their proper form, they are ignited for an hour, under sand, and taken out the next morning, when cold.* They will then be excellent conductors of galvanic electricity, although non-conductors of it before. They will not soon lose their conducting power, although exposed to the air, and if enclosed in a tight bottle, will remain perfect round the year.

* To make them perfect, they ought to be steeped in hot water, to extract saline matter, before the second ignition, as maple coal always contains it.—a. c.

will cease only on breaking the circle, and will be re-established when after such an interruption, it is restored. Of the first arrangement we have an example in two metals, with a humid disk; of the second a single metal, with diluted acid on one side and sulphuret of potash on the other; and of the third, Volta gives the instance of muscle, nerve and the blood of an animal recently dead.*

4. *All the arrangements* stated in the preceding account of muscular motions and excited sensations, *can be referred to one or another of the combinations now stated*; and as metallic combinations have proved that galvanic excitement is independent of animals, and on the other hand, animal and other substances have been so connected as to show that the power is not dependent on metals, for a galvanic arrangement has been made by slices of brain and muscle, with layers of felt, moistened with muriate of soda, and evident galvanic effects were induced.†

Batteries have been constructed with charcoal and plumbago; with disks of red beet root two inches in diameter, and other disks of the same size made of walnut wood, from which the resin had been removed by the action of cream of tartar and vinegar; a frog was excited by this last arrangement, and a leaf of scurvy grass was used for the exciter.‡

5. *In mechanical electricity, the excitement is made by means of non-conductors kept as dry as possible; in galvanism, all the bodies are conductors, perfect or imperfect, and in all energetic series, fluids are employed.*

6. *As bodies by mere contact assume opposite electrical states, their arrangement in a particular order is indispensable to the formation of a pile or battery; in a simple galvanic circle there are three bodies—*

(a.) Either two perfect conductors with one imperfect, e. g. silver, zinc, water, or,

(b.) Two imperfect conductors with one perfect, e. g. silver, alkaline sulphuret, on one side, and water or acids on the other.

An arrangement of the first kind is far the most energetic, e. g. zinc, copper, acid; if zinc and copper were repeated ever so many times, there would be no accumulation of power; the two ends of the series are exactly as if there were only one pair; but by the interposition of the fluid, an accumulating series is formed.

* Murray, quoting Journal de l'Ecole Polytechnique, Tome iv, p. 286.

† La Grave, in Memoirs of the Galvanic Society, at Paris; quoted by Wilkinson, Vol. ii, p. 338, note.

‡ This pile was constructed by M. Gautherot, (Wilkinson, Vol. ii, p. 175,) of 40 layers of charcoal and plumbago, which afforded a strong and pungent taste with a flash of light, and decomposed water, the hydrogen being given out on the charcoal side.

§ Nich. Jour. Vol. xviii, p. 159.

7. *The most energetic combinations are formed by a fluid, and two metals, as remote as possible in their chemical characters, viz. one as liable as may be, to be acted on by oxygen, acids, &c. and the other as little.*

8. *Many such arrangements may be formed, e. g. gold, silver or copper, with tin or zinc, but, no two metals are at once so energetic and cheap as zinc and copper, and galvanic arrangements are now almost universally made of them, while almost any fluid will answer, more or less perfectly, to connect them, but, in general, those are the most efficient whose chemical action on one of the metals is the most decided.*

DAVY'S* TABLES OF SOME GALVANIC CIRCLES.

Two Perfect conductors and one Imperfect.

Most oxidable substances.	Less oxidable substances.	Oxidizing fluids.
Zinc,	{ With gold, charcoal, silver, copper, tin, iron, mercury. Gold, charcoal, silver, copper, tin. Gold, silver, charcoal. Gold, silver.	{ Solutions of nitric acid in water, of muriatic acid, of sulphuric acid, &c. Water holding in solution oxygen, atmospheric air, &c. Solutions of nitrate of silver and mercury. Nitric acid, acetic acid. Nitric acid.
Iron,		
Tin,		
Lead,		
Copper,	Gold, silver.	
Silver,	Gold,	
Platinum.		
Charcoal.		

Two Imperfect conductors and one Perfect.

Perfect conductors.	Imperfect conductors.	Imperfect conductors.
Copper,	Solutions of hydrogenated alkaline sulphurets, capable of acting on the first three metals, but not on the last three.	Solutions of nitrous acid, chlorine, muriatic, or other acid, &c., capable of acting on all the metals.
Silver,		
Lead,		
Tin,		
Iron,		
Zinc,		
Charcoal.		

* Sir H. Davy, in 1826, gave a table of the electro-chemical relations of metals, (see Phil. Trans. for that year,) the first being positive with respect to the second, and so on.

With common acids—Potassium, barium and zinc, and their amalgams; cadmium, tin, iron, bismuth, antimony? lead, copper, silver, palladium, tellurium, gold, charcoal, platinum, iridium, rhodium.

With alkaline solutions.—The alkaline metals and their amalgams; zinc, tin, lead, copper, iron, silver, palladium, gold, platinum, &c.

With solutions of hydro-sulphurets.—Zinc, tin, copper, iron, bismuth, silver, platinum, palladium, gold, charcoal.

If the fluids used with the metals afford oxygen, those metals which attract it the strongest will be positive, but if these fluids afford sulphur, that metal which under the given circumstances attracts it most strongly, will form the positive pole; thus, with iron, copper, and water or acids, the iron will be positive, and the copper negative; but with solution of sulphuret of potassa, it is the reverse. With any metal, the side that touches the acid is negative, and that touching the alkaline or sulphuretted alkaline solution is positive.*

PILE OF VOLTA.

The theoretical views of Volta, led to the following arrangement.

1. *Zinc, copper, cloth, paste board, or felt, wet with almost any diluted acid or saline solution, or even with common water; this will form a galvanic series, a simple galvanic circle, and a wire passing from the zinc to the condensing electrometer, will discover positive and one from the copper, negative electricity.*

2. *A compound galvanic circle is formed by a repetition of such series as the above, always preserving the same order.*

3. *The number and size of the plates admit of much variety, it will be more fully explained farther on—in the pile, the plates are commonly of the size of a dollar,† and after 40 or 50 repetitions, the pile becomes capable of giving a shock and a spark, and of producing chemical decompositions.*

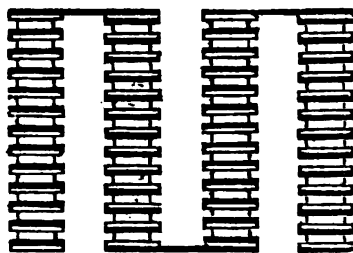
4. *Commonly the pile is mounted upon a pedestal of baked wood, and the plates are sustained by three glass pillars or by rods of baked wood.*

5. *Advantages of the pile; portable and cheap; disadvantages, very troublesome to lay up and arrange and clean, especially in large combinations.*

The trouble of cleaning the plates is, in some measure, diminished by soldering them together.

Pile.

Connected Piles.

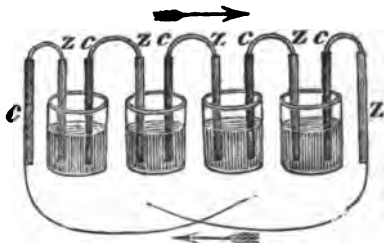


* Davy's Elements.

† I remember seeing dollars and other coins, used in some of the early piles.

COURONNE DE TASSES OF VOLTA.

1. If the zinc and copper pieces, instead of being in contact, are connected by a wire or metallic strap and immersed, separately, in any of the exciting fluids, contained in glass or earthen vessels, a simple galvanic circle is formed; and by a repetition of this series, so that a piece of zinc and a piece of copper may always be in the same vessel, but not in contact, and connected only by the fluid, an accumulating series will be formed.



2. In this arrangement a double surface of metal is exposed to action, and the pieces are easily cleaned, but as it requires numerous vessels and a large proportionate quantity of fluid, it is now, except for illustration, seldom used in the form above exhibited.

Before proceeding to describe the more powerful kinds of apparatus, I will deviate from the chronological order to mention a galvanic instrument which is very elegant and highly instructive in relation to the theory of this subject; the most remarkable circumstance is that the substances are all dry.

ELECTRICAL COLUMN OF DE LUC.

1. M. De Luc,* in consequence of his able dissection of the Voltaic pile,† was led to examine whether a liquid is essential to the effect; he mounted a pile with dry instead of wet cloth, and found that electric effects were still produced, although somewhat weaker than before.

2. After many experiments, in which he substituted various animal and vegetable substances, he came to prefer writing paper, and constructed a pile of 800 groups‡ of tinned iron and Dutch gilt paper,§ keeping the copper constantly the same way.

3. This apparatus affected the electrometer more powerfully than any Voltaic battery had ever been observed to do, but produced no chemical decomposition.

4. Mr. Singer adopted the arrangement of thinly laminated zinc, writing paper, and the same covered with silver leaf; thus the arrangement was zinc, paper, silvered paper, zinc, &c.; the silvered side of the paper being always so placed as to come in contact with the zinc.

5. The pile may be reared between three varnished rods of glass, or it may be and now generally is placed in a dry glass tube, whose

* A distinguished French philosopher then residing in England.

† See Nicholson's Jour. Vol. xxvi, p. 118, and Singer, p. 441.

‡ The size may be even less than half an inch, and the pieces may be shaped by a punch.

§ So called; it is paper covered with copper or brass leaf.

ends are covered with sealing wax and capped with brass; one cap may be cemented on, before the plates are introduced and the other afterwards; the caps should have a screw ending in a hook outside; this screw serves the double purpose of bringing the pieces into perfect contact and of securing a communication. The paper must be dried by the sun* and not by a fire.

6. Mr. Forster found that, by 1500 groups, a ball might be made to vibrate, without intermission, between two small bells, and thus to produce a constant chime. This is conveniently shown by arranging from 1200 to 1600 groups, in two columns of equal length; they are insulated, in a vertical position, by glass pillars; the positive end of one is placed lowest, and the negative end of the other, and as they are connected at the top, they may be regarded as one column. A bell is fixed on the lower end of each column, between the cap and the insulation, and a ball is suspended by a thread of raw silk, so as to hang midway; a wire is passed from bell to bell, till the clapper is fixed, and on removing the wire, the motion commences; a glass covers the whole. Mr. Lukens, of Philadelphia, whose ingenuity as a philosophical artist is well known, constructs the columns, with a metallic vane, vibrating on a delicate watch spring, between the two bells. (See the fig. on the next page.)

7. A column of Mr. Singer, of 1200 groups, rang fourteen months, except when it was moved, and was in action more than three years. M. De Luc's vibrated for two or three years, without ceasing. Prof. Griscom has a double column made in London, which was in action about three years.

8. A column of 1000 series, laid horizontally on the caps of two electrometers, will cause their leaves to diverge, with positive and negative electricity, respectively; on touching either extremity of the column, the leaves of the electrometer connected with it collapse, and those of the other open wider.

9. The motions of the interposed pendulum, although in general tolerably regular, are sometimes singularly wild and rapid; then they become slow and almost cease, and then begin again and so on.

10. The two ends of a column should never be, for any time, connected by a conducting substance, for this very much impairs its energy; when laid by, it should rest upon two sticks of sealing wax, and a column which has been injured as above, will recover its power by insulation for a few days.

11. An apparatus, after being in action thirty months, was taken to pieces, and no appearance of oxidation could be discovered on the zinc. Prof. Berzelius kept a pile formed of brass and tin papers, in which the tin is the positive metal, in action for eight years, and the tin paper remained, to the last, as brilliant as at first.†

* Mr. Lukens objects to sun-drying in that variety of the apparatus, in which manganese is used; see p. 644.

† Edin. Jour. July, 1830.

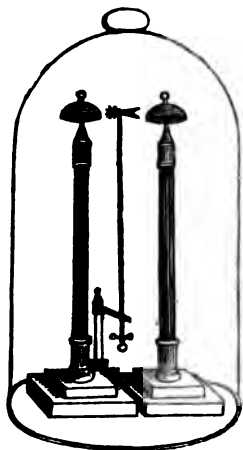
12. *A column of 1000 series will charge a Leyden jar in from 1 minute to 5, so that a small but distinct spark will be obtained by a fine wire. 20,000 groups caused pith balls $\frac{1}{2}$ of an inch in diameter, with strings 4 inches long, to diverge more than 2 inches; by bringing a very fine wire from one end into connexion with the other, a thin layer of varnish being interposed, a series of minute bright sparks was obtained.*

A contact of 10 minutes with a jar of 50 square inches of coated surface, gave such a charge as to communicate a disagreeable shock as far as the elbows and shoulders, and with some persons even across the breast; the same charge perforated thick drawing paper, but not a card, and fused one inch of platinum wire of $\frac{1}{32}$ th of an inch in diameter. It had not however, the slightest chemical action.*

These piles have been differently constructed, as by fixing fine zinc by glue and sugar upon the back of Dutch gilt paper, and cutting it into disks.† Another variety, constructed by Zamboni of Verona, was made with silvered paper, on the back of which was spread black oxide of manganese and honey, and two thousand groups of these pairs were associated; they were then covered with varnish of shell lac and enclosed in a hollow brass cylinder; two of these piles being placed at the distance of four or five inches, a light needle suspended on a pivot, vibrated freely between them.

A pendulum of a clock has been moved in this way.‡ Although piles, in which the paper is perfectly dry, scarcely act, because the paper becomes a non conductor, the conducting power is restored by heating the piles up to 104° or 140° . A double column, constructed by Mr. Lukens, which stands in my study, often begins to vibrate in cold weather as soon as the fire has brought the temperature up to a certain point, and then it will ring for hours and cease again as the room grows cold; the same thing happens in dry and hot weather in summer. A figure of this apparatus is annexed.§

In constructing these batteries, Mr. Lukens takes what is called silver paper, and the black oxide of manganese finely powdered, and mixes the latter with a saturated solution of the sulphate of zinc to such a consistence, that it may be



* Singer's last chapter.

† Phil. Mag. Vol. xlvii, p. 265.

‡ Phil. Mag. Vol. xiv, p. 261; Ann. de Ch. et de Ph. Vol. xi, p. 190, and H. Vol. ii, p. 189.

§ I have had it five years, and although it has never been kept covered, its energy, after being made clean and warm, is always found to be undiminished.

laid on the blank side[§] of the silver paper with a paint brush, where it is left to dry, not less than twelve hours; but Mr. Lukens states that the sun should by no means be permitted to shine on the papers during their drying, for in every instance where that has been the case the column has been rendered inactive. Great care must also be taken in the selection of the manganese, as what is commonly sold in the shops is not to be depended on, at least, Mr. Lukens has never found it to answer. In forming the disks, he places a number of the sheets together, and with a gun-wad punch cuts them out; they are then arranged in the glass tubes, with the silver side up in one column, and the manganese up in the other.*

Battery of metal and air.

Mr. Watkins has constructed "a pile of perceptible tension," with plates of zinc, only polished on the one side and rough on the other, without any moist conductor; they are placed parallel in a wooden frame at the distance of 1 or 2 millimeters, so that there is a thin layer of air between them, and the combination is air, rough zinc, smooth zinc, &c. and the rough zinc is positive, as when the place of the air is occupied by a liquid.†

GALVANIC TROUGHS OR BOXES.

The pile of Volta had done wonders for galvanism, but it *received an important modification from Mr. Cruickshanks*,‡ who substituted plates for disks of metal, and gave them a new arrangement.

1. *The plates are placed in a trough or long box of mahogany or other firm dry wood*,§ and cemented in grooves cut at right angles to the sides. The distance of the plates may vary from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch, or more, according to the size of the plates.

2. *The zinc plates may be cast in sand*,|| or more accurately in a brass mould. When they are 4 inches in diameter they may be $\frac{1}{2}$ of an inch thick; a thin plate, as long as it is sound, is as powerful as a thick one, and there is no reason for ever casting them thicker than is mentioned above, except to have them last longer.

3. *The copper may be the thinnest* that is used for the *sheathing of ships*; the plates are to be cut to the proper size and soldered to the zinc at the edges, for about $\frac{1}{4}$ of an inch in width.

4. *The plates should be arranged in the trough in one order*, as copper, zinc; copper, zinc; copper, &c.; which must not be reversed, and when different batteries are connected, the copper termination of one

* Communicated by Mr. Lukens, in a letter. at the request of the author.

† Edin. Jour. July, 1830, and Am. Jour. Vol. xix, p. 376.

‡ Of Woolwich, Eng.

§ I have seen them of deal, and I have often had them made of the common wild cherry of this country, but mahogany is preferable.

|| I have had them cast very well in that manner, but generally in a brass mould, in which case they are more smooth and regular.

should be opposite to the zinc termination of the other; large batteries should be connected by strips of copper or lead, or by large rods of lead or other metal; not by small wires.

5. *Cement and cementing*.—Yellow wax 4 oz. rosin 8 oz. and 1 oz. fine brick dust,* or rosin 6 lbs. dry red ochre 1, dry plaster of Paris $\frac{1}{4}$ lb., and $\frac{1}{2}$ of a pint of linseed oil; the latter makes the cement tough.

The plates and trough are well warmed, and hot cement is poured in till it floats, $\frac{1}{2}$ of an inch deep; the warm plates are now pushed into the grooves quite to the bottom, and when the cement is cool, a slip of board is tacked to the top edge of one of the sides, so that when the trough is laid flat, there is an interval between the board and the plates, into which very hot cement is to be poured, and it will flow between the pairs of plates so as to cement one side of all the cells perfectly; the other side may be treated in the same way, and then the instrument, being cleaned and varnished, is fit for use. This method of construction, which I have often practised, although not the most economical of power, is so simple and easy, that I have generally preferred it, especially, as the instruments are used with little trouble.

PORCELAIN TROUGHS.

These are now in general use, and are strongly recommended by the more perfect insulation established between their cells, which, as the divisions are also of porcelain and form a part of the box, are not liable to leak into each other; the entire box is also tight, and is protected from fracture by an exterior box of wood.

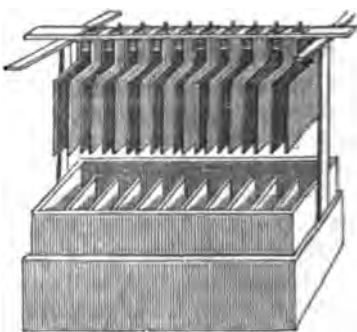
1. *The plates are connected by metallic arcs*, so placed, that they bestride the divisions of the trough, and the plates in any particular cell are always one of copper and one of zinc; they belong however, not to the same pair but to different pairs. *Usually ten pairs of plates are arranged in one trough*; they are screwed to a beam of wood, and the action can at any moment be suspended, by lifting them out; and by suspending them over the trough, they can be at any time, let down into the acid again.

2. *This mode of construction is excellent*, except that it requires a large quantity of fluid, for the cells must be so wide that the contiguous plates will not touch when immersed, and they must also admit of the easy plunging of the pairs of plates, so that a zinc and a copper of different pairs, should always be in the same cell; for it takes con-

* For general electrical purposes, rosin, 5 lbs. bees wax, 1 lb. red ochre, 1 lb. plaster of Paris, 2 table spoonfulls; the two latter ingredients to be very dry and added when the rest are in complete fusion. Another well adapted to large Voltaic batteries, is composed of rosin, 6 lbs. red ochre, 1 lb. plaster of Paris, $\frac{1}{4}$ lb. and $\frac{1}{2}$ pint of linseed oil.—*Singer*. The first named in the text should have a proportion of wax somewhat larger, as the cement is otherwise, prone to crack; that defect is remedied by the oil in the second. In these cements, ochre is not so good as the brick dust as it creates an effervescence and inflates the cement, but this would doubtless be prevented by previously igniting it.

siderable time to arrange a large series, and the loss of power is great before we can bring it to bear on the subject of experiment. The annexed wood cut, being intelligible from inspection, needs no explanation.

3. *Dr. Hare effected the insulating of the plates by using hollow glass parallelpipeds, cemented into a wooden trough, which, by turning upon pivots, enabled the acid, at any moment, to run off from the plates into a receptacle forming a part of the box, and from which, by revolving in the opposite direction, it might run back again upon the plates.*



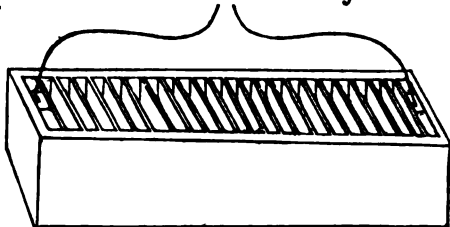
4. It is obvious, that *the instrument just described is on the principle of the Couronne de Tasses of Volta*, and the same object has been effected by cementing glass partitions into mahogany troughs, and introducing the plates, connected in pairs by a metallic strap, as above.

5. I had a battery of one hundred and fifty pairs of six inch plates constructed upon this plan, and I obviated the necessity of having large cells by using an instrument of wood shaped like a comb; by thrusting this in between the plates I was enabled to guide them correctly, and the battery was very efficient; but the glass plates were often broken, and as they became frequently loose, I have not renewed this construction.

6. It was expected also, that in such an apparatus, in consequence of the exposure of a double surface of metal, a very great increase of power would be obtained; the power is higher, but by no means in the ratio expected, while the greater expense in the first cost and also in the larger quantity of fluid required in using it, with the much more rapid waste of the zinc plates, make it doubtful, whether, on the whole, it is a very serious improvement, unless we surround the zinc entirely by copper, at the edges as well as the sides.

7. *The number of plates in a trough and the distance of the pairs must be regulated by their size; the number should be diminished, and the distance of the pairs increased, as the size is augmented.*

Cruikshanks' Battery.



ZINC SURROUNDED BY COPPER.

The power of galvanic batteries is very considerably increased, by surrounding the zinc on all sides with copper, agreeably to the suggestion and example of Dr. Wollaston.

Dr. Robert Greenhow, of New York, in 1822,* invented an excellent battery upon this construction; the copper is folded into tight cells, which contain both the zinc and the acid, and the other peculiarities will be understood from the annexed figures and description, abridged from that of the author.†

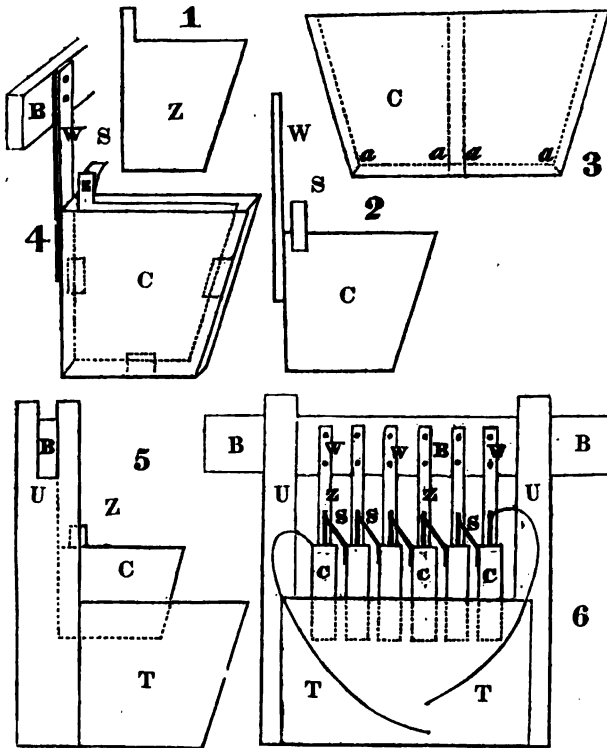


Fig. 1. Plate of rolled zinc, with a projection to receive the copper slip that forms the connexion between a copper cell and the zinc plate of the next cell.

* Med. and Phys. Jour. of New York, Vol. ii.

† Eng. Quar. Jour. Vol. xxviii, p. 72. In Dr. Brewster's Edin. Jour. Vol. iv, p. 19, under date of August, 1825, there is a description of a similar apparatus, by John Hart; there is nothing in which it differs materially from the apparatus of Dr. Greenhow, who is, without doubt, the inventor of this very neat, economical and efficient battery; his first publication is three years in advance of that of Mr. Hart. Mr. Hart's copper cells hang centrally under the beams, and the zinc plates are suspended and support the cells.

2. Copper cell, open at top and every where else closed.
3. Copper sheet, marked with slits, *a, a, a, a*, and lines, for folding it accurately, to form the cell.
4. U, varnished iron, soldered to a copper cell, to support it from the common bar, B; Z, zinc plate, with its projecting piece; S, copper connecting slip; the zinc plate is prevented from touching the copper, by slitted pieces of wood, boiled in copal varnish; the copper plate, suspensory and connecting slip, are well varnished on the outside, and also the soldered part within.
5. End view of the whole instrument in action.
6. Front view. T, trough of wood, to contain the exciting fluid; W, W, uprights, notched to receive the suspending bar; there are wires also, to complete the circuit between the poles. The action is suspended by emptying the cells, and renewed by immersing and lifting them by the bar, which is again placed in the notches. When the cells are entirely immersed, there is very little power in heating a wire of given dimensions, but on lifting the plates out it is instantly heated to a high degree. This instrument is compact; the cells are half an inch wide and one fourth of an inch apart, and therefore a great power may be comprised within a small space.

SIZE OF GALVANIC BATTERIES *in relation to utility.*

We have it, on the authority of Prof. Davy, that all the experiments by which he made his early galvanic discoveries, "may be repeated by means of a Voltaic battery, containing from 100 to 150 plates, of four or six inches," and most of his operations were performed, with a power of 100 plates of six inches.*

1. Batteries of different sizes and powers are adapted to different purposes. *The most useful are composed of plates from 4 to 6 inches in diameter.*

2. If the surface of metal be given, *the power of giving a shock to the animal frame, and of decomposing compound substances, is directly proportioned to the number of plates, while the power of burning the metals and of igniting charcoal is dependent on the size of the plates.* A battery of 50 plates whose diameter is twelve inches, is very powerful in burning the metals and in igniting charcoal, but does not give a very strong shock, while, if the same plates be cut down into 200 of 6 inches in diameter, the power of burning the metals and of igniting charcoal, will be found to be greatly reduced, while that of producing the shock and of decomposing compounds will be greatly increased.

3. *If we are to have plates of but one size, and arranged in batteries of the common construction, four inch plates should be preferred; 200 pairs will be efficient in giving shocks and producing decompositions, and double that number will produce brilliant deflagrations; 100 pairs of 6 inch plates, in good condition, will be very efficient in all experiments of fusion and ignition; and 6 inch*

* By observing, with care, the excellent directions given by Mr. Faraday, (Chemical Manipulation,) a much smaller number of plates will answer for a private experimenter, provided he allows sufficient time for the effects; in the rapid demonstrations of a public lecture, a higher power is desirable.

plates are about a proper medium for deflagrations and decompositions ; but those of 2 or 3 inches will answer for shocks and for some decompositions.

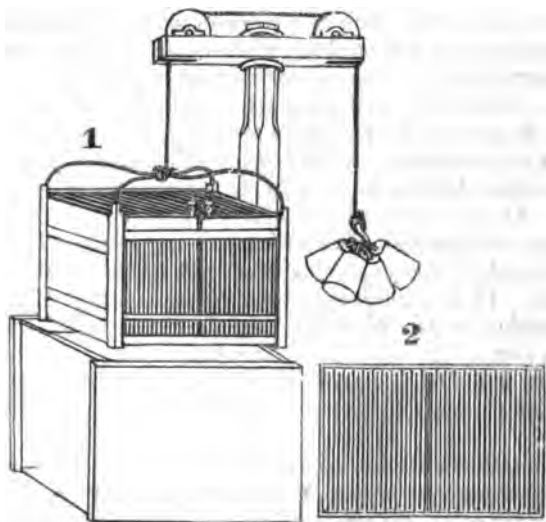
4. As a minimum, to produce the muscular shock, Mr. Wilkinson found, that with a battery of 600 plates of about half an inch square, the shock was violent, but grew feeblér at every touch till it was scarcely perceivable at the tenth shock ; but when it had been left about five minutes, the strength was recovered, and so on at equal intervals.

5. In general, *there is no perceptible difference between the shock perceived from a certain number of small or large plates, nor in the decomposing power, except so far as it depends on heat.*

6. *It appears,* however, that the power of batteries whose individual plates have equal surfaces, is as the number.* The number of the plates being fixed, *the power of ignition increases in a very high ratio with the increase of the surface, probably higher even than the square.*

7. *Very small and very large batteries ought not to be connected, e. g. 6 inch or 10 inch plates with. 1 inch, but those of the two former sizes may go together.*

CALORIMOTOR, invented by DR. HARE, in 1819.



1 The entire instrument ready to be plunged. 2. A view of the top of the plates.

Remarks.—Dr. Robert Hare, Professor of Chemistry, &c. in the University of Pennsylvania, was led to the invention of this instru-

* Davy's Elements, p. 87.

ment by reflecting that "as the number of pairs in Volta's pile had been extended, and their size and the number and energy of interposed agents lessened, the ratio of the electrical effects to those of heat had increased; till in De Luc's column they had become completely predominant, and on the other hand, when the pairs were made larger and fewer, (as in Children's apparatus,) the calorific influence had gained the ascendancy; he was therefore led to go farther in this way, and to examine whether one pair of plates of common size, or what might be equivalent thereto, would not exhibit heat more purely, and demonstrate it to be, equally with the electric fluid, a primary product of Galvanic combinations."*

1. With this view, *Dr. Hare constructed a single pair in which 20 copper, alternating at the distance of half an inch, with 20 zinc plates, each about nineteen inches square, were supported vertically in a frame, and all the plates of the same metal were soldered to one metallic bar, so that they formed but one plate, and both kinds of metal but one pair.* When the poles of this apparatus were connected by a wire, and the plates were all plunged into the same portion of acid contained in a vessel without partitions, the wire became intensely ignited, and often kindled the hydrogen gas, when that gas was evolved. There is, in the mean time, no other indication of electricity than a slight taste, such as a piece of zinc and another of silver, not an inch square, will produce, when made to touch over the point of the tongue, as in the original experiment of Sultzer.

2. *Dr. Hare found, that when all the zinc plates were arranged on one side, and all the copper on the other, without alternation, the effect was no greater than might be expected from one pair of plates.*

Alternation then is necessary to the greatest effect, and it was attained by Dr. Patterson and Mr. Lukens, by using "two continuous sheets, one of zinc the other of copper, wound into two concentric coils or spirals;" this apparatus produced ignition without sensible electricity. In a similar apparatus constructed by Mr. R. Peale, and in another by Mr. Wetherill,† the former one third more extensive than that of Dr. Hare, and the latter twice as extensive, the power was found to lessen as the size was increased, for neither of these coiled pairs would produce a heat above redness in the smallest wires.

3. *In another modification of his apparatus of large plates, Dr. Hare caused ten zinc plates, on one side, to be connected with ten of copper on the other, the ten remaining plates of the same name, on each side, being connected with each other, and finally the connexion between these now great plates, the one of copper and the other*

* Am. Jour. Vol. i, p. 416.

† These instruments were constructed a year or two before those of Col. Offerhaus and Mr. Peppys.

of zinc, being established at the poles, by a metallic wire, it became vividly ignited and burned as soon as the mass of plates, forming but two huge alternating pairs, were immersed in a common vessel without partitions. Mr. Peale, at Dr. Hare's suggestion, separated the two surfaces of his great coils into four alternating ones, so as to constitute two galvanic pairs in one recipient, when it easily burned iron wire and fused platinum.*

This is the construction of a calorimotor in my possession, made under the direction of Dr. Hare; the plates are 18 inches square; there are 9 of zinc on one side, alternating with 10 of copper, and 10 of zinc on the other side alternating with 11 of copper, 40 plates in the whole, and 90 square feet of surface; the outside plate is copper on both sides, so that the zinc surfaces are, every where, opposed to copper, and this is all the insulation that there is, as the cubical box into which they are plunged has no partition. The plates are connected by large bars of tin, gashed by a saw, so as to receive the metals, which are secured also by solder, and the alternating plates are cut down, so as not to be in the way of the bars that connect the opposing surfaces. *Not only alternation of the plates but a repetition† of the pairs, to at least two, is necessary to produce an intense calorific effect*, the quantity being as the size, and the intensity as the number of the series.

The calorimotor will be mentioned again when we speak of the effects of galvanism. Its principal obvious effect is to produce a great flow of heat with very little electrical excitement; in this view, it is a peculiar and interesting instrument, and the name given by the inventor is entirely appropriate; he might also, (as will appear farther on) with almost equal propriety, have called it a magnetimotor.

DEFLAGRATOR, invented by Dr. Hare, in 1821.‡

Remarks.—Having arranged an apparatus of 300 pairs of small plates in such a manner that they could all be plunged nearly at the same time, Dr. Hare found that a platinum wire, (No. 16,) was readily melted by it. All persons conversant with practical galvanism know, that much of the energy is lost during the filling of batteries, and that from extensive series, shocks are often given through the floor.

* Dr. Thomson, in his late work on Heat and Electricity, has described Dr. Hare's first calorimotor, consisting of one pair of plates, but he has not mentioned the second and far more efficient calorimotor, consisting of two pairs, a construction which is altogether essential to the peculiar character of the instrument; it is described by Dr. Hare in the same memoir with the first, (Am. Jour. Vol. 1.) and it is quite necessary to take it into view in order to do justice to the scientific as well as practical design of the inventor.

† It is not true, as stated by some authors, that a given quantity of surface of two metals will evolve as much heat when in one pair as in two; whether more than two pairs, (the surface being the same,) would increase the heat, has not I believe been determined.

‡ Phil. Med. Jour.; Am. Jour. of Science, Vol. iii, p. 108.

Sir H. Davy mentions this with respect to the great battery of the Royal Institution, which, although having the double insulation of dry wood and porcelain, could not be made to act, exclusively, through its true poles, and when in action, shocks were constantly received from it by the bystanders.*

From both these causes, much power being uselessly expended, it occurred to Dr. Hare, that the maximum of effect in galvanic batteries of a given size, had never been attained.

This reflection led to the construction of the *first deflagrator*, which is composed of concentric coils of copper and zinc, connected by arches of metal, and suspended by a beam and levers, so that the metals may descend into or rise out of the acid in an instant. The zinc sheets are 9 inches by 6; the copper 14 by 6; for the copper was made to surround the zinc, forming a complete cylindrical case, and being, every where, opposed to the zinc within, at the distance of one fourth of an inch, and the plates are kept from touching by slips of wood.

At first, this apparatus was arranged in one row of 80 double coils, each $2\frac{1}{2}$ inches wide, but afterwards it was divided into two of 40 double coils each, placed parallel and properly connected; and in both cases they were made to descend into cylindrical glass jars, containing the diluted acid or aceto-saline fluid. Subsequently the glass jars were removed and the coils were allowed to descend freely into a common fluid, contained in two parallel troughs, without partitions, and to prevent communication, placed a few inches apart, with nothing but dry air between. I will not now speak of the splendid effects which I have often witnessed with this fine instrument, but will merely add that although it undoubtedly acts with rather more energy when the glasses are used, still the difference is not sufficient to compensate for the additional expense and trouble. With four rows of coils, each containing 40, in the whole 160 double coils, of zinc, 9 by 6, and copper, 6 by 14, suspended from one support and simultaneously plunging into four distinct parallel troughs, I find all the energy and convenience that can be desired. This form of the deflagrator affords the advantage of large plates within moderate dimensions; but Dr. Hare has since contrived other forms, which are still more compact, and, in proportion to the surface, equally or perhaps more efficient.

In all his instruments, the usual division of the boxes into cells being omitted, it is indispensable that the zinc, be surrounded by copper; the copper cases are open at top and bottom.† In order to

* In operating with a battery of 720 pairs of four and six inch plates, in troughs of dry mahogany, although supported by glass or porcelain, considerable shocks are often received by myself and assistants, through the stream of diluted acid, and the wet pitcher from which it is poured, the circuit being completed by the person and the moist floor.

† The fluid flows in from below, and the top is kept open to admit of the withdrawing of an injured plate.

unite this requisite with the utmost compactness, *Dr. Hare has adopted the form of flat hollow copper cases, into which the zinc plates are made to slide*, being secured in their places, and prevented from actual contact with the copper, by grooved pieces of wood, which receive the edges of the zinc and rest against the inside of the copper cases, at their ends; each zinc plate is connected by a metallic arc, with the next copper case, and so on through the whole series; these compound pairs are then packed together, either with paste-board soaked in shell lac, or with thin pieces of veneering wood, between them; they thus form one mass, to which the acid has access only at the top and bottom, where the cases are open. Thus, the advantages of surrounding the zinc,* by the copper, with the greatest possible compactness, and the least possible expenditure of acid are combined. In one variety of construction, the copper cases hang by projections attached to the zinc, from a beam of wood, and are either allowed to descend into the acid, contained in troughs below, or the beams, with their suspended cases, being stationary, the troughs containing the acid are, by a simple mechanical construction, made to ascend to them, so that in either case, the plates are instantly immersed or uncovered, at pleasure.

In the last construction of Dr. Hare, the metals are fixed in a box, which is made to revolve on pivots, and thus, by a quarter of a revolution, the acid is thrown entirely off, into another box, attached at right angles to the first, and by reversing the revolution at pleasure, the acid returns upon the plates. The copper cases used by Dr. Hare are 7 inches long by 3 wide, and half an inch thick.† This form of the apparatus, besides greater compactness, has one important advantage over that with coils, that the zinc plates, when corroded, are more easily withdrawn, without disturbing so much the structure of the apparatus, but it is not possible, within boxes of moderate size, to have, as in the other form, very large plates.

It is obvious, that in all Dr. Hare's modes of construction, *the following advantages are attained*, in a degree far greater than in the usual modes of construction.

1. *The greatest compactness*, as regards the space occupied.
2. *The greatest economy*, in the quantity of the fluid.
3. *The saving of much trouble and expense, in constructing insulating cells.*
4. *The instantaneous evolution and application of the power at its maximum*, without loss either of time or energy.
5. *The instantaneous suspension of the action and its renewal*, at pleasure, without loss of metal, acid or time.

* The copper may be sextupled, with always an increased energy; beyond that the increase of energy is slower.—*Morrichini*. See Thomson on Heat, &c. p. 514.

† This is the thickness of the entire paralleliped, the copper of which may be the thinnest that is rolled for sheathing ships.

6. *To a demonstrator of galvanism, entire freedom from hurry and embarrassment; for while he is reasoning and explaining, the action may be suspended, and the instruments are not losing but are even gaining in power.**

Revolving Deflagrator of Prof. De Butts.—An account of this elegant form of the galvanic battery, was published by Dr. E. De Butts, Professor of Chemistry in the University of Maryland, in the *American Journal of Science*, Vol. viii, p. 271, (1824,) and I must refer the reader to the memoir and the plate for the details of its construction. The alternating zinc and copper plates are each 39 inches in diameter, and are fixed, in groups of 30, between a pair of external parallel wheels of strong plank, attached to an axis and distant 10 inches apart, within which space the 30 alternating parallel plates are contained and properly secured. There are four such groups of plates arranged upon one axis, at the distance of 2 inches between the contiguous systems of metallic plates, contained between the pairs of wooden wheels, and there are, in a single cistern, (the form of which is a hollow parallelopiped,) four distinct compartments, containing the acid fluid. Into these, the different groups of plates, duly connected, are made simultaneously to descend, by half a revolution, and thus the maximum of energy of this great number of large plates is obtained, and of course the plates are, with equal facility, raised into the air again and the action suspended. When immersed in water containing $\frac{1}{8}$ of nitric acid, Dr. De Butts found it impossible to fix platinum wire, $\frac{1}{8}$ of an inch thick and several inches long, in the pincers, as it melted instantly, when in contact with the poles;† this instrument readily melted other metals and ignited charcoal intensely; it produced powerful magnetic effects, but gave neither shock nor decomposition. It is obvious, that if this ingenious arrangement had admitted of having the zinc insulated, by being surrounded by the copper, it would then have given the shocks and decompositions.

* Dr. Hare's galvanic instruments have so decided a superiority over those of the common construction, that I am willing to state, as in the text, the result of my own experience with them during eight or ten years, and that of many other teachers in this country might be cited, in support of these statements. Still *the deflagrator appears to be but imperfectly known in Europe*. Dr. Thomson mentions, that some instrument of a similar construction is used by Prof. Oersted, but I have seen no other notice of it; the calorimotor is indeed used, but the important distinction between that with one and with two pairs of plates is not always attended to, and even the most respectable and accurate authors frequently confound the calorimotor and deflagrator, (Dr. Henry, 11th ed. Vol. ii, p. 187,) or restrict the name of the latter to the flat cases, without including the coils, (Dr. Thomson on Heat, &c. p. 516.) The name deflagrator implies the peculiar power which belongs to all these instruments, in a far greater degree than to any other of equal surface, in producing the ignition of charcoal and the combustion of metals, and the principal cause of this is, that the power is used at its maximum.

† This fact strikingly illustrates the power of the instrument, but, doubtless the ingenious inventor obviated this difficulty by fixing the wires before the immersion, as is done with the other deflagrators.

Dr. De Butts also constructed other batteries of smaller plates, arranged upon the same plan; in one of these the plates were 8 inches in diameter, and it contained 48 of zinc and 96 of copper.

LARGEST* AND SMALLEST BATTERIES.

1. *The great battery of the Royal Institution* is the largest in the world; it consists of 2000 pairs of double plates, each 4 inches square, arranged in cells of porcelain in 200 troughs; the entire surface is 128,000 square inches.

2. *The great battery constructed by order of Napoleon*, consisted of 600 pairs of plates almost 11 inches square, and exposed nearly 500 feet or 72,000 square inches of surface; beside this, there is a series of 1500 plates of smaller size.

3. *Mr. Children's batteries* are composed, the one of 20 pairs of 4 feet by 2, and the other of 20 pairs of six feet by 2 feet 8 inches; the square surface of one side of one plate of the first kind is 8 feet, and of the second, 16 feet.

4. Mr. Pepys constructed a *single galvanic pair* for the London Institution consisting of two plates only, the one of zinc and the other of copper, coiled around a cylinder of wood, and prevented from touching by ropes of horse hair; the length of each plate is 50 feet, and its breadth 2, the entire surface being 400 square feet; this battery is charged by immersing it in a tub containing the dilute acid,† and it is remarkable, chiefly, for its magnetic effects, which are powerful, while it does not give a spark with charcoal nor deflagrate metallic leaves, and it ignites only very small portions of metallic wires.‡

5. *Dr. Wollaston's elementary battery*; less than one square inch of zinc included properly in a copper case, and plunged into diluted sulphuric acid, ignited a platinum wire of $\frac{1}{32}$ of an inch in diameter.§

MEANS OF EXCITING GALVANIC BATTERIES.

No very efficient battery has been constructed except with alternating metals and fluids. In proportion as the fluids are more energetic in their action upon one of the metals, the effect is, in general, greater, but more transient, and as the action is less or null, as in the dry batteries, the effect is feebler but more lasting. In the wet batteries, oxygen always combines with one of the metals, and when the action is carried on under a receiver, it ceases when the oxygen is exhausted, unless the fluid supplies that principle; in a vacuum or

* Dr. Hare's instruments will be mentioned under another head.

† Phil. Trans.

‡ It is obvious, that by arranging in two alternating pairs, it would become a powerful calorimotor.

§ Ann. Phil. Vol. vi, p. 209. A lady's silver thimble flattened, will receive a plate of zinc so as to form an elementary battery that will, as stated in the text, ignite a very fine platinum wire.

in an atmosphere of carbonic acid, it still proceeds provided the fluid be nitric acid.

1. *The cavities between the plates are filled with some saline or acid fluid*; those generally used are solutions of common salt, or alum,* with the addition of a portion of one of the strong acids; the sulphuric, muriatic, or nitric; these acids themselves are the most active agents for exciting the galvanic energy, and it is common to employ a saline solution, because it is cheaper, while a portion of acid is added to increase its activity. A mixture of a solution of common salt and muriatic acid, or of a solution of alum and nitrous acid will answer very well, but, strong nitrous acid diluted with from 20 to 40 parts of water according to the size of the battery is the best. If muriatic acid be used, it should not be diluted with more than 20 or 25 parts of water; its action is tranquil and it keeps the plates clean.

2. *One part of nitric acid with 20 or 25 of water forms a very active mixture*, especially for deflagrations, but it is expensive and its action is short.

3. *Sulphuric acid with 25 or 30 parts of water is very active*, but it produces so much heat as to soften the cement of Cruickshank's batteries; the hydrogen gas is disagreeable and the effect is transient; *for large combinations, 1 part of sulphuric acid and 1 of nitric with 60 of water form a good mixture*; this was used in the large battery of the Royal Institution and for Mr. Children's great battery. The large French battery was usually excited by 1 part sulphuric acid, 70 water, and 9 or 10 of common salt.†

4. *In large batteries mixtures of the nitric acid with either the sulphuric or muriatic are eligible*; I have found the following proportions very good, 5 lbs. of nitric and the same of sulphuric acid to 1 barrel of water; this was active and enduring; the same proportions of sulphuric and muriatic acids and water, formed a very good fluid, not so active as the former, but it acts long, and leaves the plates clean.

Muriatic acid alone, in the proportion of 16 lbs. to a barrel of water, is sufficiently active and enduring.

Sulphuric and muriatic acids, in the proportion stated above, with the addition of a portion of nitric acid, combine all the advantage of activity, cheapness, permanence, and cleaning the plates.

5. *A violent action produced by a strong acid, affords an active wire melting power, but it injures the battery and is very transient*; nor is it so good for decompositions, as a less active but more enduring mixture.

* Sal ammoniac is the most active of the salts; common salt dissolved in vinegar is the cheapest; good vinegar alone answers, but it creates a frothy effervescence, and, as it will not bear much dilution, it is not very cheap. Saline solutions, besides being weaker, are prone to crystallize on the plates.

† 1 sulphuric acid, 60 water, and 2 nitre, is very good.—J. T.

Since the invention of the deflagrator we have no longer occasion to employ very strong acids, as our maximum effect is much greater than could be obtained before, with much more extensive combinations.

GALVANIC POLARITY: EXCITEMENT BY WATER.

The zinc end of the battery is positive, and the copper negative.

If, when a condensing electrometer is not affected by one pair of plates, a wet cloth is laid on the zinc, the instrument will commonly be moved.

In an excited battery, 50 pairs will affect a delicate gold leaf electrometer without the aid of a condenser; 100 pairs will cause a distinct divergence, and by 1000 pairs, pith balls are made to diverge. A wire from one end of the battery is made to touch the cap, and another wire from the other end of the battery is brought into contact with the foot of the electrometer; the nature of the excitement is then determined by bringing excited glass or resin near to the cap of the electrometer. The facts under the present head, are derived chiefly from Mr. Singer's interesting treatise.

1. *A galvanic battery is capable of being excited even by common river water, and although its other effects will be very feeble, its power of affecting the electrometer may be greater than when it is excited by the usual fluids, and the electrical effects are greatest when the chemical action is least.**

2. 100 pairs being charged with water, produce a certain effect on the electrometer but give hardly a sensible shock; with very dilute muriatic acid, the shock is much increased, but the effect on the electrometer is diminished. In experiments with from 100 to 1000 groups, common river water constantly produces the greatest electrical effects.

3. *The real increase of electricity is proved by the interposition of a common electrical battery, between the poles of the galvanic battery.*

In a galvanic battery of 800 or 1000 pairs of plates charged with water, a very faint spark only is obtained, and with 100 pairs the effect is almost null.

But if a galvanic battery of 300 or 400 pairs of plates, charged with water, be connected with an electrical battery so that a wire may pass from each pole to the inside and outside respectively, such a charge will be obtained that a fine iron wire, passing from the outside of the electrical battery and successively striking its knob, will scintillate. 1000 pairs, in this manner, produce a distinct crackling noise and burn thin metallic leaves, although the galvanic battery itself under the existing circumstances, possessed no such power.

With 400 plates of 4 inches, charged with water, no effects are produced on combustibles, but the electrometer is affected, and an

* Volta.

electrical battery is charged, so as to produce rapid scintillations with wire, and to inflame phosphorus and fulminating mercury.

4. *By contact with a Voltaic apparatus, a single jar is always charged instantly rather higher than the battery, and will therefore affect an electrometer more distinctly; the increase of this power is always exactly proportioned to the number of plates.*

5. *A Galvanic battery unused for a time, when charged with water, gives but a feeble shock, and however extensive will hardly give a perceptible spark, but will, to a certain degree, charge the electrometer and an electrical battery.*

With a weak acid, the shock is much increased and a vivid spark is obtained, but the electrometer is less affected than before, and a battery will be less powerfully charged.

6. It follows that *a very extensive series of plates, (which may be small,) charged with water, is the best for obtaining electrical effects.* The power would probably remain unimpaired for years, and is more manifest when communicated to an electrical battery.

I believe no one has attempted to realize the ingenious suggestion of Mr. Singer,* that with 50,000 or 100,000 plates of 2 inches square, excited by water, a considerable charge might be constantly kept up by communication within an electrical battery; this opinion is strongly countenanced by the continued electrical excitement of the dry battery of De Luc.

EFFECTS OF GALVANISM.

These may all be included under,

1. Chemical Decomposition.
2. The Shock and other effects on the animal system.
3. The Spark, and Ignition, or extrication of heat and light.
4. Combustion, the same effect, aided by the air.
5. Magnetism.

I. CHEMICAL DECOMPOSITIONS.—In this immense field, only selections can be made, sufficient to illustrate some principal generalizations.

1. Messrs. Nicholson and Carlisle discovered the chemical action of the battery and pile by decomposing water, April 30, 1800, and it appears from innumerable experiments, that *the galvanic electricity possesses a general energy in decomposing compound substances.*

2. *Wires are commonly used to convey the power from one end of the battery to the other; any good conductor, and therefore any metallic substance will answer, but wires of platinum or of gold, as being but little liable to chemical change, are most commonly employed.* The subject to be operated upon is placed between the points of the two wires, which in general, must be brought pretty near to

* By whose early death science sustained a great loss.

each other, as the galvanic electricity does not easily pass through a considerable distance in the air or in liquids.

3. *When the wires connected with the two ends of the battery are placed in a tube of water, that fluid is decomposed*, and if the wires are of platinum or gold, two volumes of hydrogen and one of oxygen, are evolved in mixture, and ascend to the top of the tube; if iron wires are used, then the oxygen combines with the iron, and the hydrogen alone is evolved. This decomposition was produced by Sir H. Davy when the wires were placed in different portions of the same compound, even in different vessels, provided they were connected by some porous or fibrous conducting substance, in a moist state, so that the elements are evolved at a distance from each other, and this distance was often considerable. Thus, let wires be passed through corks into a syphon tube*

filled with water, having a small hole at the bottom; the galvanic power will evolve the the oxygen at the positive, and the hydrogen at the negative pole, and the gases may be obtained separately; and the same result is obtained with tubes placed over different vessels of water, and connected by moistened amianthus, as in the annexed figures.



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4. The general truth† may be thus stated. *Some bodies are attracted to the positive and some to the negative side of the galvanic series, and this attraction is exerted at considerable distances*, and even when another body in a fluid state is interposed between the portions of the substance acted on by the wires; in this way, substances, often very heavy, are conveyed through the interposed fluid or a moist fibrous solid, and the elements of a body are thus transported from one vessel and deposited in another.

5. *Oxygen, chlorine, iodine, and bromine, are attracted to the positive side*, oxygen in all cases, and the other three generally; the acids also pass to the same pole.

6. *Combustible bodies and metals*, and their compounds, with oxygen, forming *alkalies, earths, and metallic oxides*, are attracted by the negative pole. Or, as the law is stated by Sir H. Davy, galvanism and electricity being considered as identical, certain substances, oxygen and acids, are attracted by positively electrified metallic sur-

* Or hermetically sealed.

† Sir H. Davy's Bakerian lecture for November, 1806. Nicholson's Journal, 8vo. series, Vol. xviii, p. 321.

faces, and repelled by similar surfaces negatively electrified, while inflammable bodies, metals, metallic oxides, alkalies and earths are attracted by negatively electrified metallic surfaces, and repelled by those which are in a positive state. Thus, when water is decomposed by galvanism, the oxygen passes to the positive and the hydrogen to the negative side; *when an alkaline salt is resolved into its constituent parts, the acid collects around the positive, and the alkali around the negative wire.**

7. From among Sir H. Davy's numerous and very satisfactory experiments, a few may be selected to illustrate these positions. His apparatus was simple. Generally two small vessels of glass, or, because of the liability of this substance to decomposition, sometimes those of *agate or gold*, were employed; for particular purposes, they were of Carrara marble, of sulphate of lime, sulphate of strontia, &c. Solutions of the compounds to be acted upon were placed in the vessels, and these were generally connected by a piece of *moistened asbestos*, (amianthus) laid over the lips of the vessels, so as to communicate with the fluid. When for instance, both cups contained *sulphate of potassa dissolved in water*, and this was submitted to the action of 50 pairs of plates, of 6 inches square, at the end of four hours, the *sulphuric acid was found all in one cup, and the potassa in the other. The sulphate of soda, the nitrate of potassa, the phosphate of soda and other salts gave similar results*; their acids passing over to the positive, and the bases to the negative wire. If, instead of an acid solution, distilled water were placed in one cup, and a solution of a salt in water in the other, either the base or the acid was conveyed to the water, according as the saline solution was connected with the positive or negative wire; if with the former, the acid was retained and the base repelled to the other pole, if with the latter, the base was retained and the acid repelled. In cases where *neutral salts* are decomposed, the acid and alkali will always saturate each other, and again produce a neutro-saline compound.

8. *The containing vessels themselves, when they consisted of such substances as were liable to decomposition, yielded up their constituent parts*, although, on account of their cohesion, more slowly than fluid bodies. Thus, cups of sulphate of lime, containing distilled water, when subjected to the action of a battery of 100 pairs of plates, of six inches, gave acid in the one and lime in the other; this change was perceptible in five minutes, and very obvious in an hour. *Even metals are conveyed in this way, and insoluble earths*, as silver from nitrate of silver,† and magnesia from the sulphate of magnesia.

* The electrical character is a relative one; in most cases, bodies are attracted towards the one pole or the other, as they are combined with one principle or with another.

† Silver from the nitrate has been found, forming a film upon the connecting amianthus.

9. *Not even dense aggregates*, as glass, sulphate of baryta, fluor spar, nor the firmest stones, *can resist the decomposing powers of galvanic electricity*; they are eventually resolved into simpler forms of matter. Basalt, which contains $3\frac{1}{2}$ per cent. of alkali and 1 per cent. of muriatic acid, gave in ten hours, alkali at the negative and acid at the positive pole. Thus, as was suggested by Sir H. Davy, in the atmosphere, in waters, in soils and rocks, and in the entire crust of the globe, the action of weak electrical powers may produce decompositions which either have not been understood or have been attributed to other causes.*

10. Another fact still more singular, was discovered by Sir H. Davy. He found that the chemical affinities of substances were so completely suspended by galvanism, that they could be made to pass through solutions of other bodies between which and themselves there is the strongest mutual attraction, without either affecting them, or being affected by them. Three vessels were employed, and in one experiment, sulphate of potassa was connected with the negative wire; ammonia was placed in the middle vessel, and pure water in the third connected with the positive wire; the result was, that the sulphuric acid was conveyed through the ammonia, and was found in the water. In the same manner, sulphuric acid was conveyed through solutions of lime; with baryta it failed because it forms a very insoluble and heavy compound with the sulphuric acid; the nitric and muriatic acids were transmitted through concentrated potassa and soda; lime, magnesia, soda, potassa and ammonia were sent through nitric, muriatic, and sulphuric acids without combining with them, and, both acid and alkaline bodies were conveyed through colored vegetable infusions without changing their hue.

11. *The decompositions produced by galvanism are complete, the bodies evolved being found pure*, and the wonderful effects which have been related, appear to depend on powerful attractions and repulsions.†

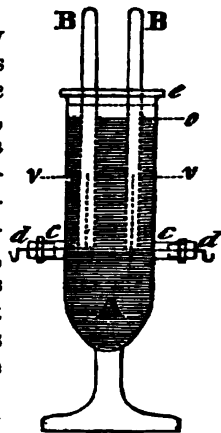
* In some former experiments it was imagined that various substances, such as potassa, soda, muriatic acid, nitric acid and ammonia, were generated from pure water, or something else; we now easily understand that they arose from galvanic decompositions of compounds really contained in the fluids. While I was in the Edinburgh school, (1805-6,) these apparent changes excited great interest, but Sir H. Davy was at that very time successfully engaged in solving the difficulty, and the splendid result was given in the Bakerian lecture of 1806.

† The classification of elements, founded on the electrical relations of bodies, as stated by Sir H. Davy, has been generally adopted by the chemical world, as it was stated in Vol. I, p. 138. But it is to be observed, as already remarked, that with many chemical elements these relations differ, as they are associated with different bodies; sulphur is positive in relation to oxygen, and when sulphuric acid is decomposed, the oxygen will be attracted to the positive and the sulphur to the negative pole; but in combination with metals, sulphur is negative and resorts to the positive pole. Oxygen is always negative, and from every combination it goes to the positive pole; hydrogen is always positive in relation to oxygen, chlorine, and other similar agents, but it is negative with respect to the metals. Professor

12. *When wires, or any thing but fluids, or porous or fibrous solids containing fluids, form the medium of communication between different vessels, there are as many sets of positive and negative poles as there are pairs of points, and the decompositions go on at all these connecting points.* Through solid matter, however good a conductor, nothing but the imponderable agents pass.

13. *It has been often stated that no currents of gas can be seen passing, from pole to pole, horizontally through decomposing fluids, and that when the decomposition of water was viewed with a magnifying power of 300,000 times, there was no appearance of a current from one wire to the other.**

This was an early observation and probably with a low power, for with a power of 720 pairs of 4 and 6 inch plates, *I have seen the opposite currents of oxygen and hydrogen gases passing, palpably to the eye, through distilled water, in horizontal planes, at different levels, and collecting in the two tubes represented in the annexed figure, both of which were found to contain the two gases, in explosive proportions, without doubt in the equivalent volumes, (as the connecting metal was platinum,) except some portions that escaped between the tubes and rose through the water.†* The existence of currents through fluids was proved by Sir H. Davy, and Mr. Porrett has shewn that a battery of $1\frac{1}{2}$ inch plates will cause water to pass, contrary to gravity, through the substance of a bladder, from the positive to the negative pole.‡



14. *Other decompositions.*

(a.) *Acids, alkalies, salts, &c.*—In strong sulphuric or phosphoric acid, for instance, the oxygen goes to the positive pole and the inflammable matter to the negative pole.

(b.) *Solution of ammonia is rapidly decomposed and its elements rise in mixture at the negative pole, the disengaged gases being hydrogen 3 volumes and nitrogen 1.*

Berzelius has constructed an approximative table of the electrical relations of bodies, which is considerably different from that of Sir H. Davy. It may be found in Dr. Turner's Chemistry, and another, although differing in the details, may be found in Thomson, on Heat, &c. p. 493. For numerous and curious facts on the electrical relations of bodies, see Sir H. Davy's last Bakerian lecture, Phil. Trans. 1826. I do not think it best to introduce a great many of these results, as the student cannot carry them in his memory; no electro-chemical classification hitherto made, is so simple and intelligible, and so easily remembered, as that of Sir H. Davy, and its truth remains unimpeached, provided the bodies are viewed in the same relations in which he contemplated them.

* Wilkinson.

† See Am. Jour. Vol. xviii, p. 199; the opposite currents flowed for hours, and were observed by many persons; the appearance was rendered very beautiful by a magnifier. B, B, the gas tubes; d, d, wires; c, c, corks; o, water level; e, cover.

‡ Thomson's Ann. Vol. viii, p. 74.

(c.) *Muriatic acid affords chlorine at the positive and hydrogen at the negative pole.*

15. *Galvanism is the most delicate test of the purity of bodies, and, unlike common electricity, its decomposing operations are often tranquil, usually without mechanical effects, and frequently without any evolution of light.*

16. *Liberation of acid and alkali from salts.*

(a.) This is beautifully seen in a syphon of this form, U filled with cabbage liquor, containing a little muriate of soda or other neutral salt; on passing the influence through, red is produced in one side and green in the other, and on reversing the connexion the opposite colors will be produced, with the intermediate production of the blue. If quicksilver occupy the bend of the syphon, and the blue fluid with the salt occupy the legs, the two colors will be produced in both sides, and the red will be seen striving to pass the quicksilver towards the positive pole and the green towards the negative, both resting on the metal.

(b.) *Acid and alkali are detected in all common waters; and even distilled water, galvanized in glass vessels, gains alkali from the glass, while the nascent oxygen uniting with atmospherical nitrogen, forms nitric acid.*

(c.) *Traces of acid and alkali have been found even in water distilled in glass and galvanized in pure gold, but not when distilled slowly in pure silver and galvanized in pure gold.*

17. *Various transfers of acid and base.*

(a.) *Diluted acid in one cup, at the negative pole, connected by moistened fibres, with diluted alkali in another cup, at the positive; they will pass each other on the way and exchange cups without combination, as may be proved by adding cabbage infusion, which at the positive pole will then change to red and to green at the negative.*

(b.) *If we arrange the same experiment only place cabbage liquor in a middle cup, it will not be affected, while the same test, added after the experiment, to both the other cups, will be changed as above.*

(c.) *Or, instead of the free acid and alkali, substitute a neutral salt, which may be placed in either of the glasses; if in the positive, the acid will remain there and the alkali will go to the negative; if in the negative, the acid will pass to the positive and the alkali remain in the negative; if in the middle, the acid and alkali will part and go in opposite directions to their respective poles, and cabbage liquor will remain unchanged in the middle glass, and be turned red at the positive and green at the negative pole.**

* In all these experiments the fibrous connexion should be large, the arch short and kept very wet; short inverted syphon tubes, filled with fluid, are still better; where there are more than two glasses the changes will not be prompt, unless with an extensive battery.

18. *Action on metals and their solutions.*

(a.) Metallic decompositions are beautifully exhibited in glass tubes, and muriate of tin, nitrate or acetate of lead, nitrate of silver and nitrate or sulphate of copper, are good examples; in an instant the metallic vegetation or deposit appears, and it is not owing to the chemical attraction of the wires, for it happens with platinum and gold, which do not chemically decompose metallic solutions; and the decomposition occurs, even when moistened amianthus or flax is the medium of communication.

(b.) Let *nitric acid* in a glass, receive a positive *platinum wire* and a negative *copper wire*; the latter will scarcely be acted on, but break or reverse the connexion and the copper will be rapidly dissolved.

(c.) In *sulphate of copper*, a negative silver wire will be coated with copper, although chemically, silver does not precipitate copper, but the reverse, for copper precipitates silver.

(d.) *Tellurium*, at the negative pole, as already stated, forms with hydrogen, a solid compound, which sinks to the bottom.

(e.) A *zinc* and a *silver* or *copper wire*, being placed, at some distance, in *dilute muriatic acid*, hydrogen is chemically evolved from the zinc, but twist them together and, galvanically, the effect is diminished, while bubbles of hydrogen gas will be evolved from the silver or copper, which is now the negative metal.

(f.) *The lead tree*, precipitated from a solution of a salt of lead by zinc, commences chemically, but after the first deposit, it is *chiefly a galvanic production*, a true galvanic circle being formed by the zinc, the revived lead, and the fluid.

(g.) In a drop of a *solution of silver*, resting on a glass plate, *place a platinum and a copper wire*; the silver collects around the copper only, but bring the wires into contact, and it precipitates around the platinum also, which is now negative and the copper positive.

19. *Oils, alcohol and ether, are decomposed by a vivid spark* taken beneath them from charcoal points; carbonic acid and carburetted hydrogen are emitted, and charcoal is sometimes deposited.

20. It has been stated already, that when animal fluids contain *albumen*, it is *separated* with alkali at the negative wire, and with acid at the positive, and if the power is strong it even coagulates at the negative wire;* hence it has been conjectured that animal secretion may depend on some such power.

21. *The splendid discovery of the galvanic decomposition of the fixed alkalies*, by Sir H. Davy, has been already stated in the first volume and need not therefore be repeated; nor the early galvanic researches on the earths which have been also detailed.

* If weaker, it separates in the fluid form.

22. *Galvanic protection of metals.*

(a.) The galvanic protectors of Sir H. Davy are well known; they were devised by him upon the principle, that the copper sheathing of ships is oxidized by the oxygen dissolved in the water, and the oxidized copper is then attacked by the acid of the muriates.

By rendering the copper negative, he deprived it of the power of combining with the oxygen by contact with which it was before rendered positive. This was effected simply by placing zinc or iron in contact with the copper, and it was found that a piece of zinc as large as a pea or the head of a small round nail, wherever placed, would protect 40 or 50 square inches of copper, and different pieces of copper joined by wires or filaments not over $\frac{1}{8}$ or $\frac{1}{16}$ of inch in diameter retained all their surfaces bright, while the iron or zinc was slowly corroded. In sheets of copper immersed many weeks in the tide water in Portsmouth harbor, where the zinc, or the cast iron or wrought iron protector, covered from $\frac{1}{8}$ to $\frac{1}{16}$ of the surface of the copper, there was no loss of weight in the latter; with smaller proportions as $\frac{1}{16}$ or $\frac{1}{32}$, there was a loss, greater as the protector was smaller, and even $\frac{1}{32}$ part of cast iron saved a certain proportion of the copper. This beautiful application of galvanism was perfectly successful in protecting the copper even in long voyages, but the sheathing became sooner foul from the adhesion of magnesia and lime,* (positively electric in relation to copper,) and the bodies of this class formed also a nidus for the adhesion of shell fish and sea weed, which, probably from the prevention of the poisoning effect by the solution of the copper, accumulated rapidly and thus impeded the sailing of the ships. By duly apportioning the size of the protectors, perhaps the copper may be preserved to a sufficient degree, and still the plants and animals be prevented from adhering. In ships constantly moored, such as prison hulks, and guard receiving ships, the adhering bodies do no harm.

(b.) Sir H. Davy suggested that instruments of brass or steel might be preserved from rusting by annexing a piece of zinc or iron, which becoming positive, will take the oxygen and preserve the brass, and Mr. Pepys, with this view, caused fine cutting instruments to be enclosed in handles lined with zinc.†

(c.) Dr. John Révere of New York, has perfectly succeeded in protecting iron from corrosion by sea water; iron spikes and even iron sheathing remaining perfectly bright after an immersion of between one and two years. The principle is the same as that of Sir H. Davy, of which Dr. R. states that it is only a successful application. He proposes not only to protect the iron bolts, spikes, &c.

* Evolved, by the galvanic decomposition of their salts.

† Phil. Trans. 1824. It has been proposed to protect the iron boilers of steam boats in the same manner.

of ships, (now in many parts rendered positive by the copper sheathing, and therefore rusting with increased rapidity,) but also to substitute plate iron for copper sheathing.*

(d.) It is proposed to protect the iron of steam boilers from rusting, by rendering the iron negative by small portions of zinc; it is an important suggestion due, I believe, to Dr. Wollaston.

II. THE SHOCK TO THE ANIMAL FRAME or effect on the nerves and muscles.

1. *The dry cuticle is almost impervious to the galvanic electricity;* if the contact be made with the hands and the poles of the battery, both being perfectly dry, the shock will be very trifling, compared with that which will be received, if the hands are first wet and then applied, and especially if each of them firmly grasps a piece of metal with which the contact is completed. If the connexion is continued, the sensation is painful, and it is always intensely so if there is the slightest cut, burn or excoriation; in such case, a very low power produces pain; the pain is said to be sharpest on the negative side.

2. *The shock extends* to the knuckles, the wrists, the elbows, the shoulders, or even convulsively through the breast, *according to the size and activity of the battery.* By a proper arrangement of the wires, it may, for medical or other purposes,† be conveyed through any part of the body, and glass tubes placed on the wires will insulate them so that they can be conveniently handled; dry gloves are a good protection.

3. *The shock is materially impaired by passing through several persons,* and will hardly pass at all, unless the hands be well moistened and firmly joined. With batteries of from 500 to 1000 pairs, there is, however, no difficulty in passing the shock through 20, 30 or more persons, with wet hands, firmly joined. If the person at one pole holds firmly a wet metallic rod, in contact with the battery, and the person at the other pole draws a similar rod rapidly over the edges of the plates, there will be intermitting convulsions, in the short intervals of time while the rod passes from one plate to another. Some persons in the circuit will be painfully convulsed; others will be more slightly affected, and others will stand almost unmoved, seeming to act merely as conductors.

4. It has already been stated, that the surface of metal being given, *the shock depends on the number* rather than on the size of the plates. In all the experiments that have been made, with a moderate number of large plates, as with Mr. Children's great battery, the

* Am. Jour. Vol. xvi, p. 180. Dr. Révere being now in Europe, I am unable to say what metal he uses to protect the iron, or what progress he has made in his important researches since the notice above cited, (Jan. 21st, 1831.)

† 50 pairs of plates 3 inches square are sufficient for most medical purposes, and double that number is more than sufficient.

shock could hardly be perceived ; but the ignition, combustion and deflagration of the metallic wires and leaves, were rapid and intense.

5. Plates one foot square will not affect the electrometer more, nor decompose water more rapidly, nor give greater shocks, than those one inch square, yet they ignite 100 times as much fine platinum wire.*

6. With large plates several persons may form a circuit, or several series of persons may form several different circuits, and all receive a shock very similar in degree and nearly like what they would have received from the same number of small plates, but if a connexion be formed by a metallic wire the shocks will cease.

7. While, as already stated, water is decomposed by platinum wires, from a battery of plates one foot square, with about the same rapidity as by those one inch square, a shock will be given to a person, grasping the polar wires with wet hands, and charcoal connected with them by wire, will be ignited nearly as well as if no connexion by water existed ; from plates one inch square, while decomposing water, there would be neither shock nor ignition.† This is usually explained upon the supposition that in the large plates, the electrical intensity is low, and the quantity of electricity large.

8. According to Ritter, the shock, when water is used, increases with the number of plates, to the extent of 500 or 600, but decreases with higher numbers ; with brine, the effect seems to be without limit ; with weak acid solutions, the shock from 1000 pairs of plates is very sharp and painful.‡ According to my experience, such a charge ought never to be taken ; if the battery is in a very active state, 600 or 700 pairs give an intensely painful and convulsive shock, varying extremely in severity, according to the sensibility of different individuals ; I have known a copious and dangerous internal hemorrhage produced by a shock from 600 pairs.

9. *Powerful muscular contractions are produced in animals recently dead, when properly connected with galvanic batteries, containing numerous plates.* An entire sheep exhibits motions resembling those of animals in a violent epileptic state. Heads of oxen may be made to open and roll the eyes, to move the jaws and tongue, and expand the nostrils, and the convulsions excited in a horse, recently killed, are almost uncontrollable. It is superfluous to describe the revolting effects so often produced upon the bodies of vigorous men, just executed ; by a skillful application of the power to different muscles and nerves, every passion and every feeling, whether of pleasure or agony, appears by turns in the face ; and strong muscular movements, agitating the whole frame, convey to the beholder the strongest impression, that life has resumed its dominion ; but among hundreds of these trials there is not a solitary case of resuscitation, and the facts remain only to prove that mimic movements

* Davy's Elements.

† Davy.

‡ Singer.

may be produced in an insensible frame as long as the last lingerings of excitability continue.

10. There can be no reasonable doubt that galvanic principles are concerned in secretion, and in many changes produced in animals, during life; but the investigation of this subject belongs to animal physiology.*

III. THE SPARK AND IGNITION.

1. *From a battery of some extent, a distinct spark, more or less vivid, is perceived every time the wires are brought into contact from the opposite poles, and it is renewed at the moment of separation.*

2. *If the poles are armed with small pointed pieces of well prepared charcoal, the light is most vivid and intense, and if the battery is powerful, the light is very enduring. It is so intense that rooms very well lighted by lamps or gas, appear comparatively dark when the galvanic light ceases.† With a large deflagrator, its overpowering effulgence must be viewed through colored glasses; with that instrument the light may be frequently renewed, with little diminution, by successive immersions of the plates.*

3. *The light is produced independently of combustion, for it takes place in a vacuum and in gases that contain no oxygen; it is exhibited, although diminished, under water, oils, ether, and other non-conducting or imperfectly conducting fluids: prismatic colors are often exhibited by galvanic light.*

4. *The galvanic spark pervades but a thin stratum of air and its striking distance is very small; with 1250 pairs, Mr. Children found it was only $\frac{1}{8}$ of an inch. When the great battery‡ of the Royal Institution, of 2000 pairs of plates, was excited by 6 parts of water to 1 of nitric acid, the poles being terminated by pieces of charcoal one inch long and one sixth of an inch in diameter, a bright spark was afforded at the $\frac{3}{8}$, or $\frac{1}{4}$, of an inch; more than half the charcoal became ignited to whiteness, and when the points were withdrawn a discharge took place, through 4 inches of air, producing a most brilliant ascending arch of light, broadest in the middle and tapering towards the charcoal.*

In this arch, platinum melted like wax in a candle; quartz, sapphire, magnesia and lime were fused; charcoal, plumbago, and the diamond, without any appearance of previous fusion, were dissipated even in vacuo.

* See Phil. Trans. 1809, p. 385, Sir E. Home.

† Galvanic light has been used to illuminate objects for the solar microscope and by Mr. Wm. Allen, in his lectures, to exhibit the phenomena of the kaleidoscope. Objects seen in galvanic light appear as they do in the sun's light.—L. V. K.

‡ In his account of this battery, (Phil. Trans. 1809,) Mr. Children mentions the remarkable fact, that if the plates are not placed at a certain distance, spontaneous discharges take place, with vivid electric light.

Oxides of tungsten and molybdenum were reduced, and columbic oxide and the oxides of titanium, cerium, and uranium were melted; diamond powder, although dissipated from the midst of soft iron, converted the contiguous parts into steel.

5. *The connexion being formed in a vacuum,* the sparks passed through half an inch*, and by withdrawing the points, the discharge took place through six or seven inches, with a beautiful corruscation of purple light; the charcoal was intensely ignited, and the platinum wire with which it was connected, was fused, and fell in large globules on the plate of the pump.

6. *This apparatus produced chemical decompositions with intense rapidity*; gave brilliant sparks and evolved elastic matter in non-conducting fluids, as oils, ether, and chloric compounds, and it produced sparks in good imperfect conductors, as nitric and sulphuric acids.

7. *The slightest contact charged the Leyden Battery so as to give a shock or a spark.†*

8. *Mr. Children's battery of 20 pairs of plates, four feet by two, as already stated, did not affect the human body more than the same number of small plates*, but a platinum wire $\frac{1}{8}$ of an inch thick, and 18 inches long, placed between bars of copper, became instantly red hot, then white hot, the light was soon insupportable, and in a few seconds the metal fell fused into globules; other metals were fused or dissipated in vapor; the ignition of charcoal was vivid beyond the sun's light.

Mr. Children's other great battery of 20 pairs, six feet by two feet eight inches, charged with sulphuric and nitric acids, in equal proportions with $\frac{1}{3}$ water, melted platinum‡ with ease, and ignited nearly six feet in length of large platinum wire, ($\frac{1}{8}$ of an inch in diameter,) but could not ignite an equal length of smaller wire; this difference was attributed to the greater proportionate extent of cooling surface in the smaller than in the larger wire, and the same appears to be true of other metallic wires; the more perfect the vacuum the more readily is the wire ignited, and the ignition may be sustained indefinitely, or as long as the battery is sufficiently active. Platinum wire may be ignited in hydrogen gas or in other gases that do not support combustion, with which process the incandescence has no connexion.

* The air being rarefied so as to support only one fourth of an inch of mercury.

† Davy.

‡ It ignited also, eight feet six inches of platinum wire $\frac{1}{8}$ inches in diameter; also a bar of the same metal $\frac{1}{8}$ inch square, and two and a half inches long; this was melted at the end; a cylinder $\frac{3}{8}$ inches in diameter, and $\frac{7}{8}$ inches long, was also ignited.—Phil. Trans. 1816.

9. *Ignition of charcoal in chlorine gas produces no change ; but phosphuretted, sulphuretted, and arseniuretted hydrogen gases are decomposed and deposit respectively their sulphur, phosphorus and arsenic.*

10. *Heat is evolved during the passage of the galvanic current, although no light should be visible.* If a slender platinum wire be inserted in any fluid and duly connected with the apparatus, the fluid will grow hot and may be made even to boil, and the ebullition may be continued. The Galvanic batteries themselves grow hot, and when very active, smoke with the rising vapor.

11. *The metals are ignited by the galvanic power with different degrees of rapidity.* The following metals were ignited by Mr. Children's great battery, in the order in which they are named—platinum, iron, copper, gold, zinc, silver, and of course their electrical conducting power is in the reverse order.* In a chain composed of alternating links of silver and platinum soldered together, the platinum links may be intensely ignited, while those of silver are not sensibly heated.

12. Among those instruments having a large surface but a small number of members, the calorimotor is preeminent, in the production of ignition in good conductors. In that of Dr. Hare, as already described, there are two pairs of alternating plates of great size ; this instrument gives no shock ; produces no chemical decompositions,† and does not move the gold leaf electrometer, nor does it ignite charcoal points however small, although in close contact, or strike through the smallest layer of air to pass even to the best conductor. But when any metallic substance with a bright surface is brought into perfect contact, by screwing it firmly into the jaws of the vices that terminate its poles, and the plates are then immersed in the acid, intense ignition follows, and combustion also, if the metal is combustible in common air. *Platinum wire is instantly ignited and melted ; a large steel knitting needle is destroyed before the plates are half immersed, and by a full immersion, iron nails of the size called nine penny and ten penny are ignited and burn vividly till the connexion is destroyed by burning in two.‡*

* For a table by Mr. Harris, of the electrical conducting powers of metals, see Dr. Thomson's late work on Heat, p. 526, and Phil. Trans. 1827.

† Except by the effect of the heat which Dr. Hare found to be sufficient to decompose hydrate of potassa by contact of incandescent iron, evolving a rose colored flame.

‡ In Dr. Thomson's late work on Heat, &c. is this passage, (p. 522) ; "a single pair supposing the surface equally great will be capable of igniting as much wire as any number of pairs of plates constituting altogether no greater extent of surface, than the single pair." Some error, probably typographical, appears to have crept in here, for the opposite was found true both by Dr. Hare and Mr. Peale, when they divided their large pairs into two alternating pairs containing the same surfaces of metal, as is stated in Dr. Hare's Memoir, Am. Jour. Vol. i.

13. *If diluted sulphuric acid is used* in this apparatus, the cistern is soon filled with innumerable *bubbles of hydrogen gas*, which, covering the top of the fluid, *often catch fire from the ignited metal*, and burn in splendid corruscations of party colored light, owing to the metals held in solution or mechanically raised.

14. *Fine magnetic effects are produced by the calorimotor*; see electro-magnetism.

15. The calorimotor, by several immersions, with little interval of time, sometimes loses to a great degree its power of igniting, although the chemical action on the metals may be increased; but by mere suspension of the plates in the air for a short time, and especially after the interval of a night, it regains its energy in the very same fluid.

IV. COMBUSTION AND DEFLAGRATION.

1. The last head and the present might have been blended, but it is more convenient to class the phenomena separately, for the light and heat may be evolved in a vacuum or in any gas, and in consequence of the intense heat generated by *the galvanic power*, it can, in the open air or in close vessels containing oxygen gas, *be applied to excite combustion* in many bodies.

2. *The inflammable fluids*, ether, oils, alcohol, naphtha, which, as already mentioned, are decomposed by passing the spark through them, *are inflamed by receiving the spark at the surface*, and in the same manner gun powder, phosphorus, and the fulminating metallic preparations are readily fired.

3. *The metals present the most interesting examples of galvanic combustion*, and they are commonly burned in the state of leaves or of wire.

If a very fine iron, when in connexion with one end of a powerful Cruickshank battery, be brought into contact with mercury connected with the other end, a vivid combustion, both of the wire and of the quicksilver takes place.

4. The best method of burning the *metallic leaves* is by *hanging them from a wire* connected with one end of the battery, and *touching them to a plate** of metal lying upon *the other end of the battery*, or to a flat plate of quicksilver properly connected. When a metallic plate is used, it should be bright or covered with gilt foil.

(a.) *Gold leaf burns* with a vivid *white* light tinged with blue, and produces a dark brown oxide.

(b.) *Silver leaf burns* with a brilliant *green* color, like emerald, and the light is more intense than from gold; the oxide is of a dark gray color.

(c.) *Copper burns* with a *bluish white* light, with red sparks; the oxide is dark brown.

* It is well to solder the plate to the connecting wire. •

- (d.) *Tin emits a white light, and the oxide is of a light color.*
- (e.) *Lead gives a beautiful purple light, very vivid.*
- (f.) *Zinc; a bluish white flame, edged at the moment of contact with red.*

The peculiar colors of the burning metals, are more distinctly seen by a contact with metal than with charcoal, whose brilliant white light absorbs the colors produced by the combustion of the metals.

Ignition and Combustion, by the deflagrator of Dr. Hare.

Under the present head, some additional notice of the peculiar powers of this instrument, is appropriate.

1. *Both in producing ignition and combustion, the deflagrators far surpass any other form of galvanic instruments.*

(a.) *Charcoal points, two inches long, were, in Dr. Hare's early experiments, instantly ignited, and the light surpasses that from any other source; it sometimes flashed through the windows upon the neighboring buildings, and it has produced dangerous inflammation in the strongest eyes.**

(b.) *At the moment of contact, or of very near approximation, a sharp rushing noise is heard, which is constantly renewed at certain distances, and is occasioned, evidently, by the passage of the electrical, calorific, and gaseous current.*

(c.) *The existence of a current, from the positive to the negative pole, is decisively proved by the transfer of the charcoal, from the positive to the negative pole; on the negative side, it rapidly collects into a knob, or projecting cone, or cylinder, which frequently becomes half an inch or more long, before it falls and gives place to another.*

(d.) *On the positive pole a correspondent cavity is formed, out of which the vaporized matter rises and collects upon the negative pole; and a new cavity can be at any moment formed in the positive charcoal, by directing the negative point to a new place upon it; the cavities have no appearance of fusion, but retain the fibrous structure of the charcoal.*

(e.) *If the charcoal points are now changed, that of the negative side retaining the projecting knobs, the latter will be immediately transferred to the other pole, whose corresponding cavity will be soon filled by the matter vaporized from the knob and after it is removed a cavity will come in its place, and thus the knob and cavity may be made, at pleasure, to exchange places.*

(f.) *If a metallic wire be fixed in the positive pole, then there is no knob formed on the negative charcoal.*

(g.) *These facts, which I first observed in 1821-22, are much less distinctly seen with a common battery, and not at all with one of mod-*

* Dr. Hare's statement of his own case.

erate size, but they constantly occur, conspicuously, with a powerful deflagrator, and have been noticed by Dr. Hare, Dr. Griscom, Dr. Torrey, and several other gentlemen in this country.

(h.) *The accumulation upon the negative pole has every appearance of fusion*, after previous volatilization; it is in shining rounded masses, aggregated often like a cauliflower; it has a semi-metallic appearance; it is harder than the charcoal, heavier, much less combustible, and burns away slowly when ignited in the air or with chlorate of potassa, and forms carbonic acid. See Vol. i, p. 358. It is obviously derived from the charcoal and must of course contain its impurities.†

(i.) *Similar appearances are produced by plumbago and to a degree by anthracite*; plumbago may be volatilized and accumulated upon charcoal, and the latter may be transferred to the former, when it exhibits beautiful tufts; the light from plumbago points is very intense and even more rich than from charcoal.

2. *Combustion by the deflagrator is exceedingly vivid*; the metallic leaves vanish in splendid corruscations; a platinum wire several feet in length, fixed between the poles while the metals are in the air, becomes red and white hot, and melts the instant they are immersed; the largest wire of this metal fixed in one pole and touched to charcoal in the other, melts like wax in a candle, and is dissipated in brilliant scintillations; a watch spring or a large steel knitting needle, fixed in the same manner and touched to the charcoal point, burns completely away with a torrent of light and sparks; a stream of mercury flowing from a funnel is deflagrated with brilliant light, and an iron wire is fused and welded to another under water.

3. *There is no perceptible impediment or loss in the flow of the galvanic current*, from another room, through a circuit of 150 feet of apparatus and communicating leaden rods;‡ the spark may be taken at any intermediate points by connecting the two sides of the battery, and very beautiful combustions are produced by running metallic leaves or

† Dr. Thomson (on Heat and Electricity page 170 note) says that he repeated the experiment and obtained "a microscopic bead,"—which consisted of the earthy matters of which charcoal is never destitute; he does not say that he analyzed it. But with powerful deflagrators the fused masses are not microscopic, they are objects for the naked eye. If they are merely fused earths, why is there no appearance of fusion on the positive pole, but a cavity from which the carbon, and every thing else is removed. With me, it happens equally well in a glass globe filled with azote; there was no volatilized charcoal collected within the glass, and in azote, there could be no carbonic acid gas formed; what then became of the carbon? Is it credible that mere earths should pass back and forward in vapor between the poles? Dr. Torrey suggests that the knob is volatilized carbon, but that the small rounded masses at the ends may admit of a question. It is only with a powerful deflagrator that these experiments are striking.

‡ The Deflagrator with coils, already described, stands in another room, and the power is brought into the lecture room by leaden conductors.

wires connected with one pole rapidly along the leaden rod which is the conductor to the other.

4. *The shock from the deflagrator is, as I have thought, rather more severe than from an equal number of pairs of the common battery; probably this is on account of its being received when it is at a maximum.*

5. *All the effects of the deflagrator are easily renewed, from day to day with the same fluid, provided we add to it occasionally a little fresh acid; it exhibits a decided magnetic energy.*

INCOMPATIBILITY OF GALVANIC INSTRUMENTS.

I beg leave to refer the reader to a series of papers and notices by Dr. Hare and by myself, contained (*passim*,) in the first eight volumes of the American Journal of Science, upon calorimotors and deflagrators and other galvanic instruments, and their various uses and applications. In the course of the experiments, mentioned in some of those papers, I observed the incompatibilities now to be mentioned.* I must refer as above, for the details, as I have room only for the conclusions.

1. *The galvanic troughs and the deflagrator paralyze each other and cannot be made to act in concert; when acting separately in full energy the power of both is, for the moment, annihilated when they are joined; still, the power of the battery will flow through the deflagrator provided its coils are in the air, but not if immersed or even if only touching the fluid at its surface.*

2. *The calorimotor does not impede the action of the troughs; it allows their energy to pass through itself, but it contributes nothing to aid their power and cannot be made to project its own power through the troughs.*

3. *The same fact is true of the calorimotor in relation to the deflagrator; the power of these instruments cannot be made to unite; only the calorimotor allows a transit to the power of the deflagrator; but the deflagrator does not, in turn, transmit the power of the calorimotor.*

4. *The calorimotor, however, when connected at once with the troughs and with the deflagrator enables them so far to unite, that the deflagrator acts through the troughs, but without deriving any increase of power from them or from the calorimotor; the calorimotor is then an intermedium for the troughs and for the deflagrator, otherwise incompatible.*

5. *It seems, hitherto, impossible to obtain any increase of power by combining the different kinds of galvanic apparatus.*

* See Dr. Hare's remarks upon this subject in Am. Jour. Vol. v, p. 105.

V. ELECTRO-MAGNETISM.

I. ACTION OF THE CONNECTING WIRE OF A GALVANIC PILE
ON THE NEEDLE.

The effects of all the galvanic arrangements alluded to in the preceding pages, take place in bodies interposed between the extremities of conductors proceeding from the positive and negative poles, or so situated as to form of themselves a part of the galvanic circuit.

1. In the year 1820, *Prof. Oersted*, of Copenhagen, reasoning upon the effects of electricity, as one of the general powers of nature, *succeeded in proving*, by experiment, *that the magnetic needle is influenced by a galvanic discharge, when placed out of the galvanic current.* This most interesting observation, led to all the discoveries that have followed, in electro-magnetism. When a wire, connecting the opposite poles of a battery in full action, was brought horizontally over a magnetic needle, and at a distance not exceeding three fourths of an inch, *Prof. Oersted* found that the needle was immediately disturbed and evinced a tendency to arrange itself at right angles to the wire; the pole next to the negative end of the battery always turning to the west. On the contrary, when the wire was carried below the needle, all the other circumstances remaining unchanged, the pole next to the negative end of the battery turned from its natural position to the east. When brought on the west side of the needle and in the same plane with it, the needle still occupied the magnetic meridian, but the pole next to the negative end of the battery was depressed; when the wire was to the east, the same pole was elevated.*

2. The energy of these effects declines with the decreasing power of the battery and with the distance of the wire from the needle; but while the battery retains any magnetic energy, contrary to what takes place in other effects of electricity and galvanism, *the influence of the uniting wire passes*, without the slightest obstruction or diminution of power on the needle, *through plates of glass, metal or wood*, the disc of an *electrophorus*, or even a stone-ware vessel containing water.

3. *The conjunctive wire may consist of any metal*; nor does it lose its effect, although interrupted by a column of water, of several inches in length.

4. It has been long known that *the electro-magnetic effect may be produced by common electricity*, discharged from a powerful electrical battery.

* The electro-magnetic experiments of *Oersted* have thus put us in possession of a galvanometer, capable of pointing out the direction of the electric current under all circumstances. When the current is interrupted, no effect is produced on the needle; but the moment it is restored, the north pole is carried to the left of the current which acts upon the needle.

5. *The galvano-magnetic phenomena are best observed with a single pair of plates, and the results are more energetic in proportion to the increased size of the plates.*

II. ATTRACTIONS AND REPULSIONS BY GALVANIC CURRENTS.

1. Not long after the discovery of Prof. Oersted, *M. Ampère found that when two currents, from different galvanic batteries, are moving in the same direction, in parallel wires, they attract each other; but when moving in opposite directions they repel.* He placed, parallel to each other, two conducting wires, uniting the negative and positive poles of a galvanic battery. One of these wires was moveable, and the effect was, that it was attracted by, and made to approach the immoveable conducting wire. When, by the aid of another battery, the currents were made to move in the opposite direction, the moveable conducting wire was repelled and receded from the immoveable.

2. From this very important experiment, and from one to be detailed farther on, Ampère has endeavored to show, that *magnetism arises from the attractions and repulsions of currents of electricity, constantly circulating around every magnet.* It is to be remarked, that the attractions and repulsions thus manifested are directly the reverse of those produced by common electricity; for it has long been known that bodies in the same state of electricity repel, and in opposite states attract each other, but electro-magnetic currents, when moving in the same direction, always attract, and in the opposite, always repel each other.

III. ROTATION OF A WIRE AROUND THE MAGNET.

Mr. Faraday's observations upon the position of the magnetic needle, with respect to the conjunctive wire, deserve to be mentioned next, although they do not follow precisely in the order of discovery.*

1. *Mr. Faraday found that the apparent attraction of the needle on one side, and its consequent repulsion on the other, did not occur under all circumstances; but that according as the wire was placed nearer to, or farther from, the pivot of the needle, attractions or repulsions were produced on the same side of the wire.* When the wire is made to approach perpendicularly towards one pole of the needle, the pole will pass off on one side, in that direction which the attraction and repulsion at the extreme point of the pole would give. But if the wire be continually made to approach the center of motion, by either the one or the other side of the needle, the tendency to move in the other direction diminishes; it then becomes null, and the needle is quite indifferent to the wire. *Ultimately the motion is reversed and the needle powerfully endeavors to pass the opposite way.*

* English Quarterly Journal, Vol. xii.

2. From these phenomena, *it was inferred that the center of magnetic action, or the true pole of the needle, is not placed at its extremity, but in its axis, at a little distance from the extremity and towards the middle,—that this point has a tendency to revolve round the wire, and necessarily, also, the wire to revolve around the point.* And as the same effects, in the opposite direction, take place with the other pole, Mr. Faraday concluded that *each pole had the power of acting on the wire by itself*, and not as any part of the needle or as connected with the opposite pole. The attractions and repulsions he regarded only as exhibitions of the revolving motion in different parts of the circle.

This revolving motion was illustrated in the following manner; a portion of mercury was poured into a glass tube, placed perpendicularly, the lower end of which was closed with a cork; a small magnet penetrated this cork, and one of its poles was pushed so far up, that it rose a little above the surface of the mercury. At the top of the tube was another cork, through which passed a piece of copper wire; at the lower end this was bent up into a hook, and from the latter was suspended a second fine copper wire, so as to enjoy a free rotatory motion on the hook, the lower end of the wire just dipping into the mercury. That the electricity might move readily through these wires, the loops by which they were connected were previously amalgamated, which increased the closeness of their contact. The mercury was now connected with one of the poles of a galvanic battery, by means of the magnet, while the wire at the top of the tube was connected with the other pole. The galvanic current was thus made to pass through the mercury and the two wires; and it was found that whenever the communication was established, the freely suspended copper wire began to revolve around the pole of the magnet, and continued to do so as long as the transmission of the power was kept up. If the wire was fixed, and the pole of the magnet rendered moveable, the latter was found to revolve in the same manner around the former. The direction of the rotation, depended upon the direction of the current, flowing through the apparatus.

If the dial-plate of a watch be supposed to represent the surface of the mercury, and the pivot in the center, to represent the north pole of the magnet; then, when the upper part of the wire was connected with the negative extremity of the battery, the lower end revolved round the magnet in the direction in which the hands of the watch move: when the connexion was reversed, or the magnetic pole changed, the motion was the reverse of that of the hands.*

* This simple arrangement was afterwards exceedingly varied by its contriver, as well as by many other persons; and a great variety of pieces of apparatus was invented, exhibiting these rotatory motions of magnetic poles around conducting wires or rather of conducting wires around magnetic poles. Of these a very convenient

net, capable of supporting a heavy bar of iron. By suspending the connexion with the battery, the force was instantly destroyed, and it was again restored by a renewal of the connexion.

2. *Dr. Moll's experiments.*—*Dr. Moll*, of the University of Utrecht,* in repeating the above experiment, *used a large galvanic surface*. The length of his horse-shoe was about eight and a half inches by one inch in diameter; the copper wire was coiled eighty three times from right to left around the iron. The ends of the wires as well as those of the battery were plunged into cups filled with mercury. *The galvanic apparatus consisted of a single copper trough, in which a zinc plate was immersed, whose acting surface was about eleven square feet. As soon as the acid was introduced, the armature lifted fifty pounds, and by gradual additions, sustained seventy five pounds.* The south pole of the magnet was on that side on which the copper spiral wire dipped into the cup connected with the zinc plate.

The magnetism was nearly destroyed by shifting the connecting wires from one cup to the other; as soon as the connexion was re-established, the magnet recovered, at once, its original strength, only the poles were reversed.

Although the horse-shoe was possessed of a magnetic force only during the action of the battery, it was found capable of communicating strong and lasting magnetism to hardened steel bars and compass needles.† The horse-shoe could not, by augmenting the strength of the galvanic apparatus, be made to support any greater weight. *Dr. Moll* also experimented with a larger horse-shoe, weighing about twenty six pounds, coated with silk and wound around, at first, with 44 turns of brass wire, the acting galvanic surface being the same as in the first instance, when it supported 135 lbs.; then with 40 turns of iron wire, it supported 154 pounds.

3. *Experiments of Prof. Jos. Henry and Dr. TenEyck.*—This class of experiments has recently, in this country, been extended in a very happy manner by Mr. Henry, of the Albany Academy, assisted by Dr. Philip TenEyck. *The object was not merely to impart to soft iron its greatest magnetic effect, but to do it by means of the smallest possible quantity of galvanism.‡*

(a.) A bar of soft iron, two inches square and twenty inches long, was bent into the form of a horse shoe, nine and a half inches high. Its weight was twenty one pounds, and that of its armature seven pounds.

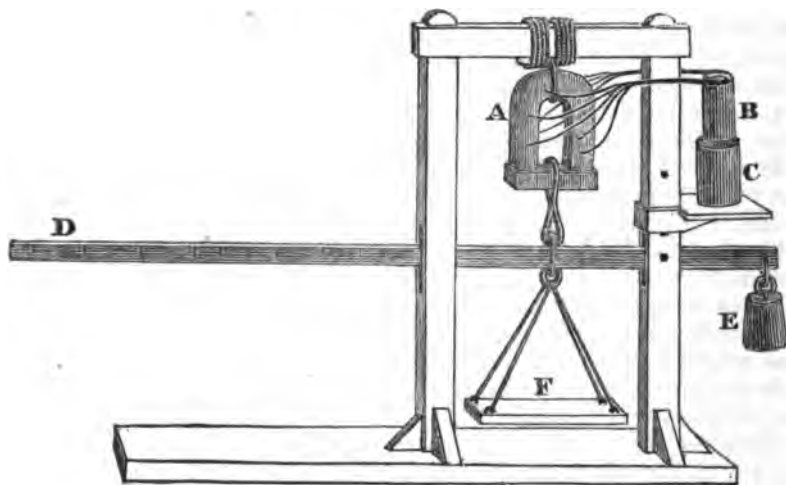
* See Am. Jour. Vol. xix, p. 329.

† Prof. Moll does not state whether the galvanic magnet could impart magnetism after it was detached from its connexion with the battery; we presume that the trials were made during its connexion.

‡ Am. Jour. Vol. xix, p. 400.

(b.) Around the horse-shoe, 540 feet of copper bell-wire were wound in nine separate* coils of 60 feet each: the coils not being continued around the whole length of the bar; but each strand of wire occupied about 2 inches, and was coiled several times backward and forward upon itself. The ends of these wires were left projecting, and all numbered, so that the first and the last end of each might be readily distinguished.

(c.) In this way, one combination of wire or more could be made by merely uniting the different projecting ends. Thus, if the second end of the first wire was soldered to the first end of the second wire, and so on through all the series, the whole would be made to form a continuous and undivided wire. By soldering different coils, the whole was capable of being formed into a double coil of half the length of the whole wire, or into a triple coil of one third the length, &c. The horse-shoe was suspended in the manner indicated by the annexed wood cut.



Description.—A, the magnet covered with linen, the ends of the wires projecting so as to be soldered to the galvanic element B. C, a cup with dilute acid on a moveable shelf. D, a graduated lever. E, a counterpoise. F, a scale for supporting weight.

(d.) A galvanic battery was used consisting of two concentric copper cylinders with zinc between them. The whole amount of zinc surface exposed to the acid was $\frac{2}{3}$ of a square foot; and the battery needed only half a pint of dilute acid for its submersion.

* For the reasons which led to this novel arrangement, see Mr. Henry's paper, *Am. Jour.* Vol. xix, p. 400.

(e.) Each wire of the horse-shoe was soldered to the battery in succession, one at a time, and the magnetism developed by each was just sufficient to support the weight of the armature of the horse-shoe.

(f.) Two wires, one on each side of the horse-shoe were then attached; the weight lifted was 145 pounds.

(g.) With two wires, one from each extremity of the legs, the weight lifted was 200 pounds.

(h.) With three wires, one from each extremity of the legs, and the other from the middle of the arch, the weight supported was 300 pounds.

(i.) With four wires, two from each extremity, the weight lifted was 500 pounds, besides the armature; when the acid was removed from the zinc, the magnet continued to support, for a few minutes, 130 pounds.

(j.) With six wires, the weight supported was 570 pounds; and with all the wires, 650 pounds.

(k.) Another battery was then employed in the place of that used for the foregoing experiments: its zinc plate measured twelve inches by six. The weight lifted in this case was 750 pounds, which appeared to be the greatest strength the magnet was capable of receiving, as a calorimotor containing 28 plates of copper and zinc, each eight inches square, did not in the least, augment its power; but with a pair of plates exactly one inch square and connected with all the wires, 28 pounds were raised.*

Mr. Henry and Dr. TenEyck have proved that a great evolution of magnetism may be made by a very small galvanic element; that the power of the coil is very much augmented by increasing the number of wires without adding to their length individually; that the current from a galvanic trough is more efficient in magnetizing soft iron, after traversing a wire more than $\frac{1}{2}$ of a mile long,† than when it passes only through the wire surrounding the magnet; that if we use a very long wire it must be connected with a battery consisting of a number of pairs of plates; that if we use a number of wires, only a single pair of plates is needed, and those that are very small will evolve great power; that the magnetism, imparted to soft iron by a galvanic current, is much greater than can be produced by the ordinary method of touching, as the most powerful magnets in Europe‡ lift but 250 lbs. and the largest magnet in this country§ lifts 310 lbs.

* Messrs. Henry and TenEyck have ascertained that, to a certain extent, the power increases by increasing the quantity of iron, without enlarging the size of the galvanic element.

† The wire was disposed in a sufficient number of turns, forward and backward, across a large room, so that the entire length was as stated in the text.

‡ See Dr. Moll's paper, Am. Jour. Vol. xix, p. 329.

§ That of Mr. Peale, of Philadelphia, made I believe, by Mr. Lukens.

With one pole Mr. Henry's magnet sustained but 5 or 6 lbs. while with both poles, it lifted from 700 to 750. Dr. TenEyck succeeded in causing a very small galvanic magnet to lift 420 times its own weight, while the strongest ordinary magnet before known would raise but 250 times its own weight.

VI. APPARATUS TO SHOW THE MAGNETIC INFLUENCE OF THE GLOBE.

1. The discoveries which remain to be stated, are among the most important relating to electro-magnetism, inasmuch as they seem to confirm the only probable theory on this subject; they are due originally to the investigations of *M. Ampère*. He *endeavored to show that a connecting wire, suspended so as to have perfect freedom of motion, was influenced, both by the electric currents in the wire and by the magnetism of the globe.*

2. His apparatus consisted merely of a copper wire bent into a circle, with the two extremities brought near each other. It was supported so as to move with the greatest facility, and the points were immersed in contiguous basins of mercury, with which the wires of a galvanic battery were connected. When the communication was established, so as to cause a galvanic current to pass through the circle, it immediately began to move, and after some oscillations placed itself east and west, or nearly at right angles to the magnetic meridian.

3. When a magnet was presented to this circle, in the direction of its axis, one pole of the magnet repelled the circle and caused it to move away; and when the opposite pole was presented, it attracted the circle, which approached, and even moved along the magnet, with the latter in its center, thus exhibiting distinct marks of magnetism, particularly, that most characteristic one, of the axis pointing always to the north.

4. If the galvanic current was, by reversing the connecting wires, made to flow in an opposite direction, the circle turned half round, and placed itself east and west.

5. A more convenient form of the apparatus was contrived by *M. de la Rive*, in which the electricity was generated without the aid of a battery. It consisted of two small plates of zinc and copper attached to cork, and connected by a spiral brass wire. When the apparatus was placed upon the surface of an acid liquor, the metals being undermost, and the whole allowed to float at pleasure, it arranged itself in the manner described above.*

* Profs. Schweigger and Poggendorf took advantage of this property, which a spiral wire has of increasing the intensity of the action of the electric current on the magnet, to construct a very useful little instrument, for the detection of the smallest possible currents of electricity, and which they call an electric multiplier. Around a

VII. THEORY OF M. AMPERE.

1. It remains only to give an outline of the much admired theory of Ampère, already mentioned, and which, for ingenuity, has rarely been surpassed.

2. The first principle of the theory has been already noticed, that *two galvanic currents attract when they move parallel to each other and in the same direction, and repel, when they move parallel to each other in contrary directions*, which is the reverse of the usual effects of electricity.

3. Hence it is inferred, that *these results depend on electrical properties*, previously unsuspected, and that they are *peculiar to electricity when in motion*, or flowing in currents. Electricity, when accumulated, has the power of producing certain effects, particularly attractions and repulsions; but when moving in currents, it exerts new powers, and these constitute magnetism.

4. To bring together concisely the various experiments mentioned in the preceding pages, so far as they bear on this point,—it has been found, that the connecting wires of two batteries attract and repel each other according to the direction of the currents flowing through them; that the magnetic needle is, in exactly the same manner, attracted and repelled by a connecting wire, according to the direction of the current moving through the wire; that whenever the circuit is broken, this influence on the needle ceases, and is renewed whenever the communication between the poles of the battery is restored; that the connecting wire, of whatever metal it may consist, becomes a perfect magnet as long as the current flows along it; that steel needles may be converted into permanent magnets, by simply placing them across the connecting wire; that the galvanic currents which possess this magnetizing power are not, like accumulated electricity, confined by glass or other non-conductors, but pass through all bodies with facility, as magnetism was before known to do; that the magnetizing power is exerted

common brass wire, silk is coiled in order to effect its insulation, and then turned into circles of fifty, one hundred, or two hundred convolutions of the wire,—the greater the number, the greater is the delicacy of the instrument. This bank of wire is kept in its position by tying it with silk thread: the two extremities of the wire being left loose and of some length are brought into contact with a galvanic pile in action, the current passes through all the windings of the wire. A very moveable magnetic needle being placed upon a proper support in the middle of this bank, is immediately affected, and turns itself so as to be at right angles to the bank. In an instrument of this description, made and sold by Mr. G. Chilton of New York, the ends of the wire are terminated, one by a small wire of copper and the other by one of zinc, which compose the whole of the galvanic battery: when they are immersed in a wine glass of dilute acid, the needle instantly places itself at right angles to the magnetic meridian.

by electricity, whether evolved by a galvanic apparatus or by a common machine ; that powerful magnets may be formed by conducting electric currents around bars of iron and steel, and that the position of the north and south poles of these magnets depends upon the direction in which the currents are made to move around them : these and a great number of other facts, it is conceived by Ampère, clearly demonstrate the identity of electricity and magnetism.

5. *Currents of electricity*, therefore, according to the theory, *are essential to the production of magnetic phenomena.* The common magnet is conceived by Ampère to be an assemblage of electric currents, moving round it in planes perpendicular to its axis ; their number being as great as that of the lines which, without cutting one another, may be imagined to form closed curves all around it. Magnetization, he says, imparts electro-motive energy to the particles of common steel, and causes a circulation of the currents to be continued round them. These currents attract all other electric currents flowing in the same direction, and repel all others which are moving in an opposite direction ; from which it follows that the currents of one magnet, have always a tendency to move any other magnet near it, till the currents in the second, shall coincide in direction with those in the first. It is important to observe also, that the electric currents flow around every magnet in the same direction in reference to its poles. If, for instance, we place a magnet with its north pole pointing to the north (in the usual position of the magnetic needle,) the current of electricity flows round it from west to east ; or, on the eastern side of the magnet it is moving downwards, and on the western side upwards ; on the upper side from west to east, and on the lower side from east to west.

6. *On these principles the phenomena of magnetism are easily accounted for.* Thus, when two magnets are attracting, the north pole of one the south pole of the other ; the electric currents must flow in the same direction, in both of them, that is from east to west, (provided the magnets are so situated that the north poles of both, point to the north) ; hence, as currents moving in the same direction, attract, the opposite poles ought to attract each other, as is found in all instances to be the case.

But suppose the poles in the most northerly magnet in this experiment, to be reversed ; let its north pole be approached to the north pole of the other ; the electric currents will continue to flow round it, in the same direction as before ; but in reference to the other magnet and to the meridian, their direction will be reversed ;—it will now be from east to west, upwards on the eastern side and downwards on the western ; consequently, the currents in the two magnets being now opposite will repel, or what is the same thing, the two north poles will repel each other.

7. *The reason why the magnetic needle so readily places itself at right angles to the connecting wire of the battery is this; in the needle, the currents flow round its axis, from end to end; in the connecting wire there is no circulation around the axis, but a constant stream from one end to the other: hence, in order that the current along the wire may coincide with the current across and round the magnet, it is necessary that the latter should stand across the former.*

The other phenomena of the needle turning to the west, when placed below the wire, to the east when placed above it, &c. are explicable upon the principle, that currents flowing in the same direction, attract; and that in every magnet they move in a constant current, which when the north pole is turned to the north, is from west to east, or upwards on the west side, and downwards on the east side.

Upon the same cause depends the development of permanent magnetism in steel needles, when placed across a wire, while the effect is only temporary when they are fastened parallel with it; in the latter case, it arises merely from the transmission of electricity from end to end, while in the former, the electro-motive energy of the particles is developed and when set in motion, seems to have the power of continuing itself.

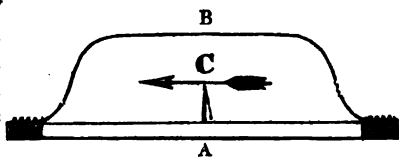
8. To complete the view of Ampère's theory, *it remains to explain the influence of the earth on the magnetic needle*, by which, it is kept in one uniform position. He conceives that *currents of electricity analogous to those which circulate around every magnet are constantly flowing around the globe*, as the current of electricity in a galvanic apparatus moves in an unbroken circuit from the negative to the positive pole, and from it, by the connecting wire, round again to the negative pole. The direction of these currents, he infers to be the same as has been stated with artificial magnets; and it is simply by the attractions and repulsions of these terrestrial currents, bringing the currents round the needle to coincide with them, that the latter always points to the north. That these terrestrial currents do actually exist, the above mentioned experiments of Ampère and De la Rive clearly prove; they employed an apparatus incapable of permanent magnetism, and the wire through which the current passed arranged itself east and west. A purely electrical apparatus, which was constructed in reference to Ampère's theory, being so distinctly influenced by the magnetism of the earth, affords a very strong confirmation of the truth of that theory; and there appears to be only one link now wanting, to connect magnetism and electricity. This is, by some combination of wires and magnets to produce an undoubted electric or galvanic effect, such as the decomposition of water. All the phenomena of magnetism may be produced by electricity; and if any of the phenomena occasioned by electricity alone can be produced by magnetism, we shall no lon-

ger be left in doubt, that these powers are identical.* Some facts having a very important bearing on this subject, were stated in Vol. I, p. 172.

THERMO-ELECTRICITY.

1. *Evolution of electricity, by heating two metals.*

It was discovered by Seebeck, that if to a bar of antimony, A, eight inches long and about an inch wide, with a slip of copper, B, or a copper wire, soldered or firmly tied to its two extremities and bent into a rectangular shape, the heat of a lamp is applied to either extremity, a magnetic needle placed within the current, as at C, will be deflected and



will tend to place itself at right angles to the magnetic meridian, showing that a current of electricity is passing through the circuit composed of the antimony and copper. Bismuth and antimony are the metals which produce the greatest effect; bismuth being the most negative, and antimony the most positive of all the metals hitherto tried as thermo-electrics.

The application of heat is not indispensable to produce thermo-electric effects. If we apply ether to any part of the antimony bar and allow it to evaporate, or even a piece of ice, a deviation in the inclination of the needle takes place; showing that the evolution of electricity depends upon the difference of temperature in the different parts of the metallic chain.

It has also been ascertained that liquids may be made to act as thermo-electrics. The concentrated sulphuric, nitric and muriatic acids, are more negative than bismuth, while the concentrated fixed alkalies are more positive than antimony.

* With regard to the cause of electric currents inferred to be constantly circulating round the globe, it is as yet in obscurity. They are supposed to move at right angles to the magnetic meridian, or nearly parallel with the equator, on the eastern side of the earth from us, and on the western side flowing towards us. These currents may be compared to that which flows from the negative pole of a voltaic battery in full action, to the positive pole, and by the medium of the uniting wire round again to the negative pole. M. Ampère supposes that the arrangement of the materials of the globe may be such as to constitute a battery, existing like a girdle round the earth, which, though composed of comparatively weak elements, may be sufficiently extensive to produce the effects of terrestrial magnetism. Its irregularity and the changes which it may accidentally or periodically suffer, may explain the phenomena of the compass needle; or the general action producing the currents of electricity, may be affected by different causes, as the earth's motions, currents of the atmosphere, evaporation, or the solar heat. It is supposed that much of the variation depends on the progress of oxidation in the continental regions of the globe. What is called the diurnal variation, is considered to be caused by the diurnal change of temperature in the superficial layers of the earth, which possess electro-magnetic energy. See an interesting paper on the observed magnetism of the earth, by Capt. Sabine. (communicated by Prof. Renwick.) Am. Jour. Vol. xvii, p. 145.

Professor Cumming discovered that rotary motions may be induced by thermo-electrics, as well as by common electro-magnetism. Platinum and silver were soldered together in a circular form, poised upon a magnet and heated by a spirit lamp; the heat being applied to the platinum wire, the rotation was produced.

2. *Thermo-electric effects, by heating one metal.*

A single metal is sufficient to produce these effects, provided there be differences in its texture and cohesion. Seebeck cast, separately, rings of antimony, bismuth and zinc, taking care that certain parts of them were cooled much more rapidly than others. The parts rapidly cooled assumed a fine grained texture and a greater degree of density, while the other portions of the ring, that were slowly cooled, became crystalline. When these rings were heated at the point of contact of the different textures, the magnetic needle was immediately affected.

(I have omitted to state, in its proper place, that flame has electric polarity; that of burning phosphorus, being acid, is bent towards the positive pole, and that of a candle containing ignited carbon, towards the negative.)

* * * * *

The above is only an outline of some of the principal facts and conclusions relating to the very interesting topic of electro-magnetism, the extensive investigation of which belongs to general physics. Numerous papers on this subject are to be found in all the journals of science, published during the last eight or ten years, and the treatise of J. F. Demonferrand, on *Electro-Dynamics*, translated and illustrated by Prof. Cumming, of the University of Cambridge, (Eng.) may be consulted.

THEORY OF GALVANISM.

Remarks.—From the statements that have now been made, it is evident that during the last forty years, and more particularly the last thirty, galvanic phenomena have excited the most intense interest in the scientific world; by the innumerable experiments and elaborate researches of the ablest philosophers, so many facts have been accumulated, that it is not easy either to arrange them, or to condense them within convenient limits.

Having however attempted the performance of this task, we might perhaps, with little loss to the student, omit any other speculations as to the theory of galvanism, than such as are necessarily connected with the statement of the facts. The extended discussions on galvanic theory, which still continue to be maintained,* prove suffi-

* See particularly Sir H. Davy's last Bakerian lecture, *Phil. Trans.* 1826, and Prof. De La Rive's *Memoir*, *Ann. de Chim. et de Phys.* Vol. xxxvii, p. 225.

ciently that the subject is not yet finally settled, and that, for the present, omitting indecisive disquisitions, we must accept of the most probable hypothesis.

The principal theories that have been proposed to account either for the origin or mode of galvanic action, are,

1. The electrical theory of Volta.
2. The Chemical theory.
3. The Electro-chemical of Sir H. Davy.
4. The theory of Dr. Hare.

1. *The electrical theory of Volta.*—As regards this theory, the most important fact has been already stated, namely, that *different bodies brought into contact assume, at the moment of separation, opposite electrical states*; this appears to be sufficiently established, and is generally admitted.*

Still, *it is not proved that bodies are in opposite electrical states, when in contact*; the experiments which have been already stated, prove that they are so at the moment after separation. Taking however both propositions for granted, it follows that *in each pair of zinc and copper plates in a galvanic battery, the zinc† is positive and the copper negative*; as long as the different pairs remain unconnected by a fluid or by moisture, there is in the series no accumulation of power; but as soon as a fluid is interposed, the electricity which had been accumulated in each of the zinc plates by the influence of the copper, flows onward towards the zinc or positive pole, in consequence of the conducting power of the fluid; thus an accumulating series is established, each copper plate becomes more negative, and each zinc plate more positive, in consequence of the connexion by the fluid, until the extreme deficiency is found in the first copper plate, and the extreme accumulation in the last zinc plate. *When the communication is made by a conductor between the poles of the battery, there is then a discharge of the accumulated power*; but as the metals remain constantly in contact, the electricity is again moved and continues to flow through the fluid which is supposed to act only as a conductor, and no effect is attributed to its chemical action.

The metals were therefore called by Volta, electro-motors, and to their mutual influence he attributed the evolution of the power which he regarded as being exclusively electricity. Had there been however no chemical action of the fluids on the metals, and had the energy of the pile been proportioned only to the conducting power of the fluid, the theory of Volta would have been more stable; but it

* The arguments in opposition to this view may be seen in M. De La Rive's Memoir, already cited.

† In this view zinc takes electricity from all the other metals, (commonly known,) and gold yields it to every other.

was first observed, especially in England, and afterwards in other countries, that the energy of the pile is intimately connected with the chemical action of the interposed fluid upon one of the metals.

2. *The chemical theory*, which arose from the observation of this fact, *imputed the evolution of the power to the chemical action.* Dr. Wollaston inferred that in the common battery, the oxidation of the zinc is the primary cause of the electric excitement. The principal facts that support this opinion have been already stated. *There is no very efficient combination in which oxygen is not imparted to the zinc;** the acids that oxidize it most readily are generally the most powerful in exciting galvanic action, and pure water is entirely inactive, especially in a vacuum or in a gas which cannot impart oxygen. *Still, it will be remembered that river water is more effectual in producing the merely electrical phenomena of the battery than even the strong acids.* I have often observed the chemical action on the zinc (especially when diluted sulphuric acid was employed,) to be energetic, when the galvanic energy was feeble. In the apparatus, which is more powerfully and continuously electrical than any that has as yet been constructed, (De Luc's and Zamboni's,) the chemical action is the least possible. It seems indeed not to be exactly decided, how far the excitement in this apparatus is connected with chemical action. It is usually stated that the zinc, after some years, becomes tarnished, and that then the action ceases; in the pile of Berzelius it appears, however, as already stated, that the metal, (tin,) was not tarnished, although the pile had been eight years in action. It is said that the action will not commence if the papers have been thoroughly dried; still, an increase of temperature will revive the action when it has been suspended.

It seems, at present, impossible to decide, how far chemical action is the efficient cause of galvanic excitement; it is certain that the one is not directly proportioned to the other; that they are however, intimately connected cannot admit of a doubt; but who can say which is first; which is cause and which is effect? It seems then, that neither the electric theory alone, nor the chemical theory alone, is sufficient to account for galvanic phenomena. Can the two theories be combined? This was attempted by Sir H. Davy, with his usual felicity.

3. *The electro-chemical theory.*—It is necessary here to repeat, that electric excitement is apparently produced by the mere contact of different bodies, and to admit that they may remain excited while in contact; it has been already explained how electro-motion, without any chemical action, is supposed to be established in each pairs of plates;

* It has been recently ascertained by M. de la Rive, that the impure zinc of commerce is much more efficient than pure zinc; the latter dissolves much more slowly in acids; the metallic impurities of the former, lead, tin and iron, enable it, even without copper, to act galvanically upon the acid.—*Am. Jour.* Vol. xix, p. 372.

and that if this were all, there would be no transfer of accumulated electricity from one pair of plates to another; such a combination would therefore be entirely inactive. It is admitted by the advocates of the electro-chemical theory, that when the fluid is interposed, the accumulated electricity of each pair flows on to the next, and the zinc end becomes as highly positive as the copper end is highly negative. But it is supposed that *the energy of the combination would be only momentary were not the equilibrium* that has been destroyed in each pair of plates instantly restored, and the chemical agency is supposed to effect it in the following manner. The decomposition of the fluid commences; for instance, oxygen or acids, which when in combination, are supposed to be negative, are attracted by the positive zinc and combine with it; in the mean time hydrogen or the base, (perhaps an alkali) being positive, passes to the copper, and thus, either by combination or contact with these bodies, the disturbed equilibrium of each pair of plates is restored, but it is for the instant only; for the metals being still in contact, the electro-motive power operates as at first and the equilibrium is again broken; but the decomposition still proceeds; the positive and negative principles of the fluid are again attracted to their respective surfaces, and thus the operation goes on, until, the liquid being all decomposed, or the surface of the metal saturated, the action ceases.

By this theory, then, *the electro-motive power of Volta is sustained by the chemical action*, and although neither of the postulates of the chemico-electrical theory has been decidedly proved to be true, still, this hypothesis is more probable than either of those singly, from the union of which it is formed. The probability of its being true is considerably increased, by the well known fact, that by altering the electrical relations of bodies, we can modify, exalt, destroy, or reverse their chemical action. Several cases of this kind have been already stated, and no one is more remarkable than that of the galvanic protectors of Sir H. Davy.

That illustrious philosopher conceived that the atoms of matter may be endowed, naturally, with opposite states of electricity, and that thence may arise chemical combination, which is of course subverted when, by a proper connexion with a galvanic battery, the combined bodies are brought to have the same electricity or are attracted more powerfully by the excited metals than they are by each other; as there is no direct proof that the atoms of bodies are endued with opposite electricities, I shall not enlarge upon this beautiful hypothesis, which may be found, in detail, in Sir H. Davy's Elem.; in his Bakerian Lecture,* and in all recent systems of chemistry.

* Philosophical Transactions, 1826.

Theory of Prof. Hare.

As regards the cause by which the galvanic power is evolved, the theory of Dr. Hare is not inconsistent with either of those that have been very concisely sketched.

The peculiarity of his view respects rather the nature of the power than the mode in which it is evolved; although in estimating its nature, important inferences are drawn from the different modes of excitement. Dr. Hare believes, that the Voltaic power is a compound of caloric, electricity, and light.*

Dr. Hare remarks, that heat is liberated by the Voltaic apparatus in a manner and degree not imitated by mechanical electricity; the latter much more rapidly pervading conductors, but effecting even the slightest decompositions with difficulty; that caloric permeates all matter although with very different degrees of facility, radiating instantaneously through air and imparting repulsion to the particles of matter but not to masses; that electricity passes on the surfaces† of bodies and does not radiate through matter,‡ and while it is conducted by some bodies with almost infinite velocity, it passes through others only by a fracture or perforation; that it causes repulsion between masses but not between particles; that electricity, passing off readily by conductors, and caloric by radiation, or, combining with contiguous matter, the two would not, unless in some way modified by their union, pass on, through thousands of galvanic pairs; through moisture, which so readily conducts away electricity, and through air which is so favorable to the radiation of heat; that pure electricity does not expand the slips of gold leaf between which it causes repulsion, nor when caloric produces ignition in contiguous masses, is there any repulsion manifested between them; and that as the galvanic power pervades the interior of bodies and produces corpuscular repulsion it is more allied to caloric than to electricity, and he, therefore, proposes to call it electro-caloric.

Dr. Hare conceives that in deflagrations by the Leyden jar, the electricity combines with the caloric, existing in a latent state, between the particles of the metal, and thus the increased repulsion overpowers the cohesion; that the continued ignition of a wire and of charcoal at the Voltaic poles is easily explained upon his theory, for accumulated heat as well as electricity flows through the series, and the charcoal is intensely ignited, because being a bad con-

* At the time of the formation of his theory, magnetism had not been observed in Voltaic combinations; Prof. Oersted's discoveries were made in 1819, the very year in which Dr. Hare's first memoir appeared in the Am. Jour. (Vol. 1, p. 413, July.)

† A globe or cylinder of metal, if a mere shell, will receive just as much electricity from excited glass as if the metal were solid.

‡ See a very interesting paper on *Radiating Electricity*, by Prof. Bonycastle, of the University of Virginia.—*Eng. Quart. Jour.* Vol. XXIX, p. 134.

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4. The theory of Dr. Hare.

1. *The electrical theory of Volta.*—As regards this theory, the most important fact has been already stated, namely, that *different bodies brought into contact assume, at the moment of separation, opposite electrical states*; this appears to be sufficiently established, and is generally admitted.*

Still, *it is not proved that bodies are in opposite electrical states, when in contact*; the experiments which have been already stated, prove that they are so at the moment after separation. Taking however both propositions for granted, it follows that *in each pair of zinc and copper plates in a galvanic battery, the zinc† is positive and the copper negative*; as long as the different pairs remain unconnected by a fluid or by moisture, there is in the series no accumulation of power; but as soon as a fluid is interposed, the electricity which had been accumulated in each of the zinc plates by the influence of the copper, flows onward towards the zinc or positive pole, in consequence of the conducting power of the fluid; thus an accumulating series is established, each copper plate becomes more negative, and each zinc plate more positive, in consequence of the connexion by the fluid, until the extreme deficiency is found in the first copper plate, and the extreme accumulation in the last zinc plate. *When the communication is made by a conductor between the poles of the battery, there is then a discharge of the accumulated power*; but as the metals remain constantly in contact, the electricity is again moved and continues to flow through the fluid which is supposed to act only as a conductor, and no effect is attributed to its chemical action.

The metals were therefore called by Volta, electro-motors, and to their mutual influence he attributed the evolution of the power which he regarded as being exclusively electricity. Had there been however no chemical action of the fluids on the metals, and had the energy of the pile been proportioned only to the conducting power of the fluid, the theory of Volta would have been more stable; but it

* The arguments in opposition to this view may be seen in M. De La Rive's *Memoir*, already cited.

† In this view zinc takes electricity from all the other metals, (commonly known,) and gold yields it to every other.

was first observed, especially in England, and afterwards in other countries, that the energy of the pile is intimately connected with the chemical action of the interposed fluid upon one of the metals.

2. *The chemical theory*, which arose from the observation of this fact, *imputed the evolution of the power to the chemical action.* Dr. Wollaston inferred that in the common battery, the oxidation of the zinc is the primary cause of the electric excitement. The principal facts that support this opinion have been already stated. *There is no very efficient combination in which oxygen is not imparted to the zinc;** the acids that oxidize it most readily are generally the most powerful in exciting galvanic action, and pure water is entirely inactive, especially in a vacuum or in a gas which cannot impart oxygen. *Still, it will be remembered that river water is more effectual in producing the merely electrical phenomena of the battery than even the strong acids.* I have often observed the chemical action on the zinc (especially when diluted sulphuric acid was employed,) to be energetic, when the galvanic energy was feeble. In the apparatus, which is more powerfully and continuously electrical than any that has as yet been constructed, (De Luc's and Zamboni's,) the chemical action is the least possible. It seems indeed not to be exactly decided, how far the excitement in this apparatus is connected with chemical action. It is usually stated that the zinc, after some years, becomes tarnished, and that then the action ceases; in the pile of Berzelius it appears, however, as already stated, that the metal, (tin,) was not tarnished, although the pile had been eight years in action. It is said that the action will not commence if the papers have been thoroughly dried; still, an increase of temperature will revive the action when it has been suspended.

It seems, at present, impossible to decide, how far chemical action is the efficient cause of galvanic excitement; it is certain that the one is not directly proportioned to the other; that they are however, intimately connected cannot admit of a doubt; but who can say which is first; which is cause and which is effect? It seems then, that neither the electric theory alone, nor the chemical theory alone, is sufficient to account for galvanic phenomena. Can the two theories be combined? This was attempted by Sir H. Davy, with his usual felicity.

3. *The electro-chemical theory.*—It is necessary here to repeat, that electric excitement is apparently produced by the mere contact of different bodies, and to admit that they may remain excited while in contact; it has been already explained how electro-motion, without any chemical action, is supposed to be established in each pairs of plates;

* It has been recently ascertained by M. de la Rive, that the impure zinc of commerce is much more efficient than pure zinc; the latter dissolves much more slowly in acids; the metallic impurities of the former, lead, tin and iron, enable it, even without copper, to act galvanically upon the acid.—*Am. Jour.* Vol. xix, p. 872.

This is an outline of the reasons which have induced Dr. Hare to conclude, that *light, caloric and electricity are original and in relation to each other, collateral products of galvanic action*, which in a manner inexplicable or at least unexplained, puts them into circulation, the heat, as already stated, being in the compound proportion of the extent of surface, and of the number of the pairs, and the extent of contact with the solvent; that these principles (material as he supposes) become thus more susceptible of transfer, either by union with each other or with some unknown matter which regulates the galvanic and magnetic movements, and that thus they may be recognizable by our senses, while passing into or out of ponderable matter, in which chemical or galvanic changes are taking place; that the renovation of galvanic power by repose of the apparatus out of the fluid implies a secret source whence, mediately or immediately, the imponderable powers are supplied from surrounding matter;* that in the galvanic circulation, the electric fluid may be prevented from escaping through the solvent, because it is in union with the heat, and the heat can scarcely pass through the fluids except by the circulating power which it derives from the electricity, and this agent, in turn, subdues the propensity of the caloric to pass off by radiation; that thus vivid ignition is exhibited by charcoal which retains much of the heat but permits the electricity to pass freely, and that air, even in a thin stratum, produces a similar effect by dividing the heat and the electricity, the latter passing off by a continued stream, and the former by radiation; that in the communication of the galvanic power through a wire, the electricity easily passes, and the heat is partially detained and uniting with that which is in a latent state in the metal, an active ignition is the result; that in the column of De Luc, electricity being predominant and caloric evanescent, charcoal is not ignited because there is not heat enough to produce that effect, and on the other hand, in the calorimotor, the ignition of charcoal is prevented, because there is not sufficient electricity to project it through a substance so unfavorable to the passage of heat, while, by the same instrument, metallic masses are readily ignited since they oppose much less resistance to the passage of heat, and none at all to electricity.

I have thus given a more detailed statement of Dr. Hare's theory than of those that preceded it; because, in my judgment, it well deserves an attentive examination, especially as it presents, in strong re-

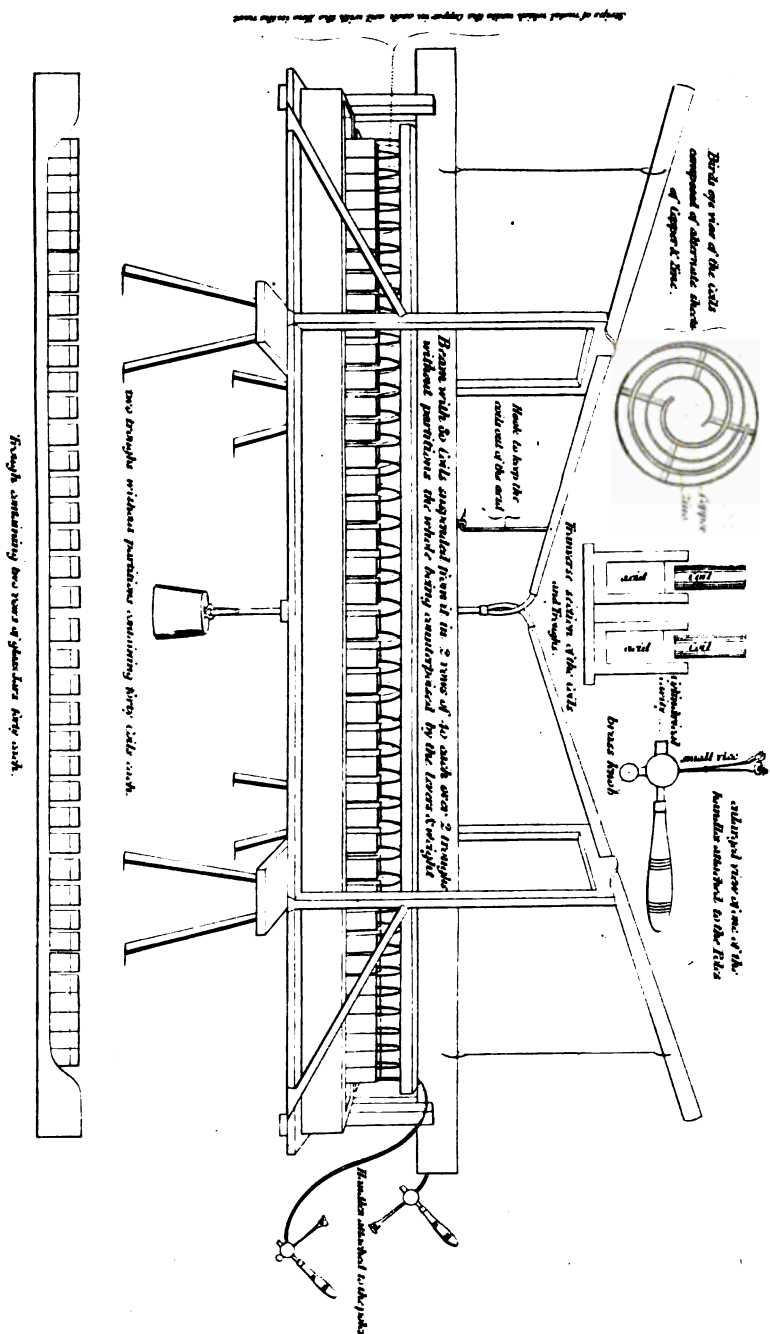
* Since the discovery of the battery composed of air and zinc plates with rough and polished surfaces, we can scarcely hesitate to admit that the ignition of platinum sponge by hydrogen gas may be a galvanic phenomenon.

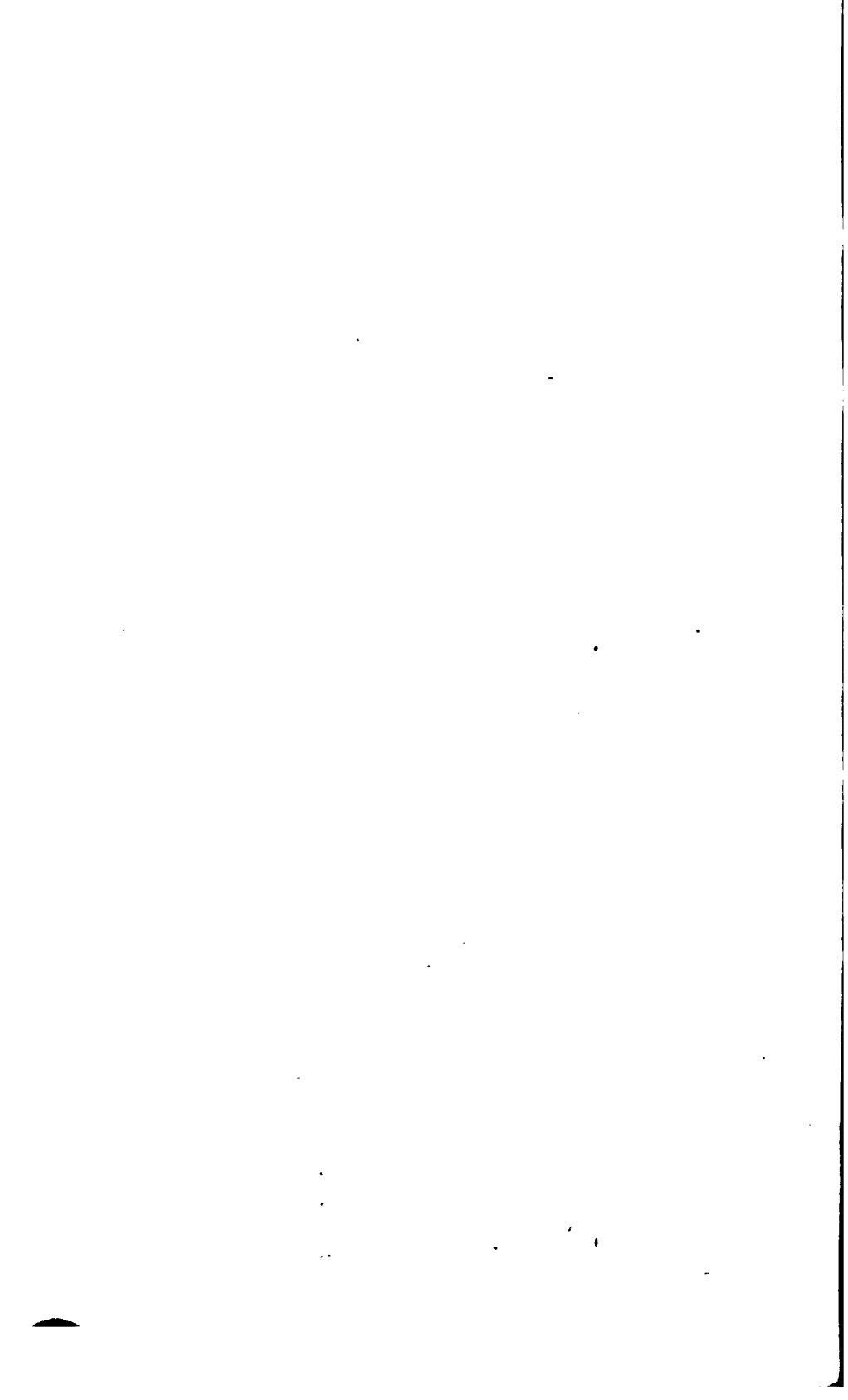
lief, those formidable difficulties in the subject which are usually disposed of, with little discussion, under the broad divisions of intensity and quantity.* While we admit the distinction as having a real foundation, we cannot think that the difficulties of the subject are in that manner solved, and we may still well ask, *what is electricity?* If it is agreed that it shall stand for all the phenomena (as exhibited by galvanic instruments,) that belong to light, heat, magnetism and decompositions, as well as for those that, before the discovery of galvanism, were regarded as purely electrical; then, with this broad use of the term, we may admit those other powers and their effects as modifications or appendages of electricity; but if we continue to regard them as distinct powers, *we can scarcely attribute to one cause the varied effects of galvanic action.* Thus we have at one time, magnetism in great energy, without either perceptible heat, light, electricity, or decomposition, (as in the fine results of Dr. Moll,† and the still finer of Mr. Henry,‡) in another case, intense ignition and magnetism, with scarcely perceivable electricity or decomposing power, are exhibited, as in the calorimotor; in another, electricity without decomposing power, and (unless in very extensive combinations,) without heat or light, as in the column of De Luc; in other combinations, as in the common batteries and deflagrators, all these powers are united; and in short, in the various instruments, every imaginable proportion and manifestation of all those effects may be obtained, from the maximum of one or more of them, to the minimum or evanescence, of others. In the present view of the subject, must we not therefore, conclude with Dr. Hare, that *the cause is as occult as the origin or nature of gravitation.* In the actual state of our knowledge, will it not be the safest course to admit, that *the luminous, calorific, magnetic, decomposing, and electrical effects of galvanic instruments are all original products of the imponderable agents,* thus mysteriously set in motion, and that we are, as yet, in no proper condition to decide with confidence, whether they are the result of one power variously modified, or of two or more, or whether there is a distinct cause for each of these classes of effects.

* Dr. Thomson, in his late work on Heat and Electricity, mentions Dr. Hare's view, but does not discuss the difficulties which it is intended to meet, except by referring them to differences in intensity and quantity.

† Am. Journal, Vol. xix, No. 2.

DOE HEARSES GALVANIC DEFLACATOR.

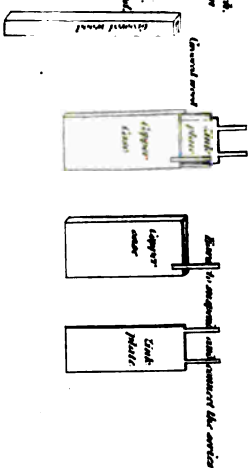




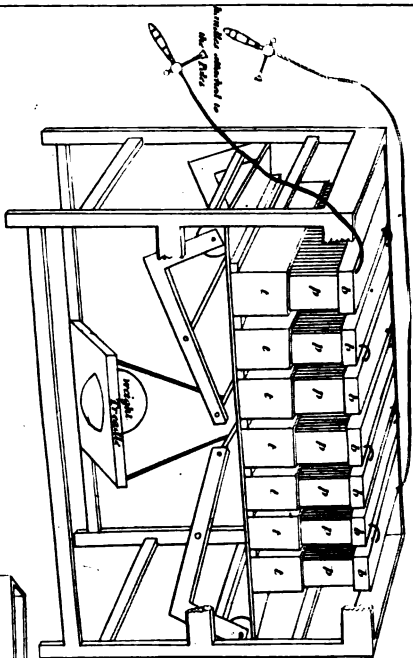
DR. HARE'S NEW GALVANIC DEFLAGRATORS.

Plate 2.

Between each case is placed a piece of parchment soaked in shell lac varnish.

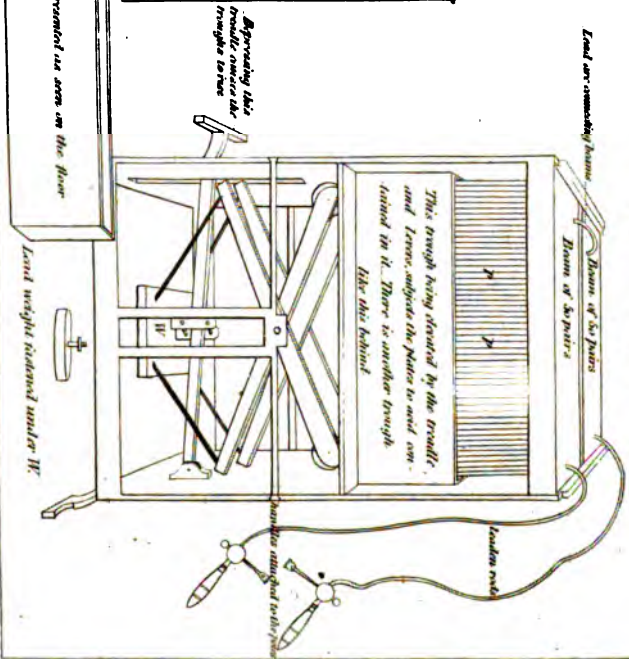


Deflagrator of 350 pairs



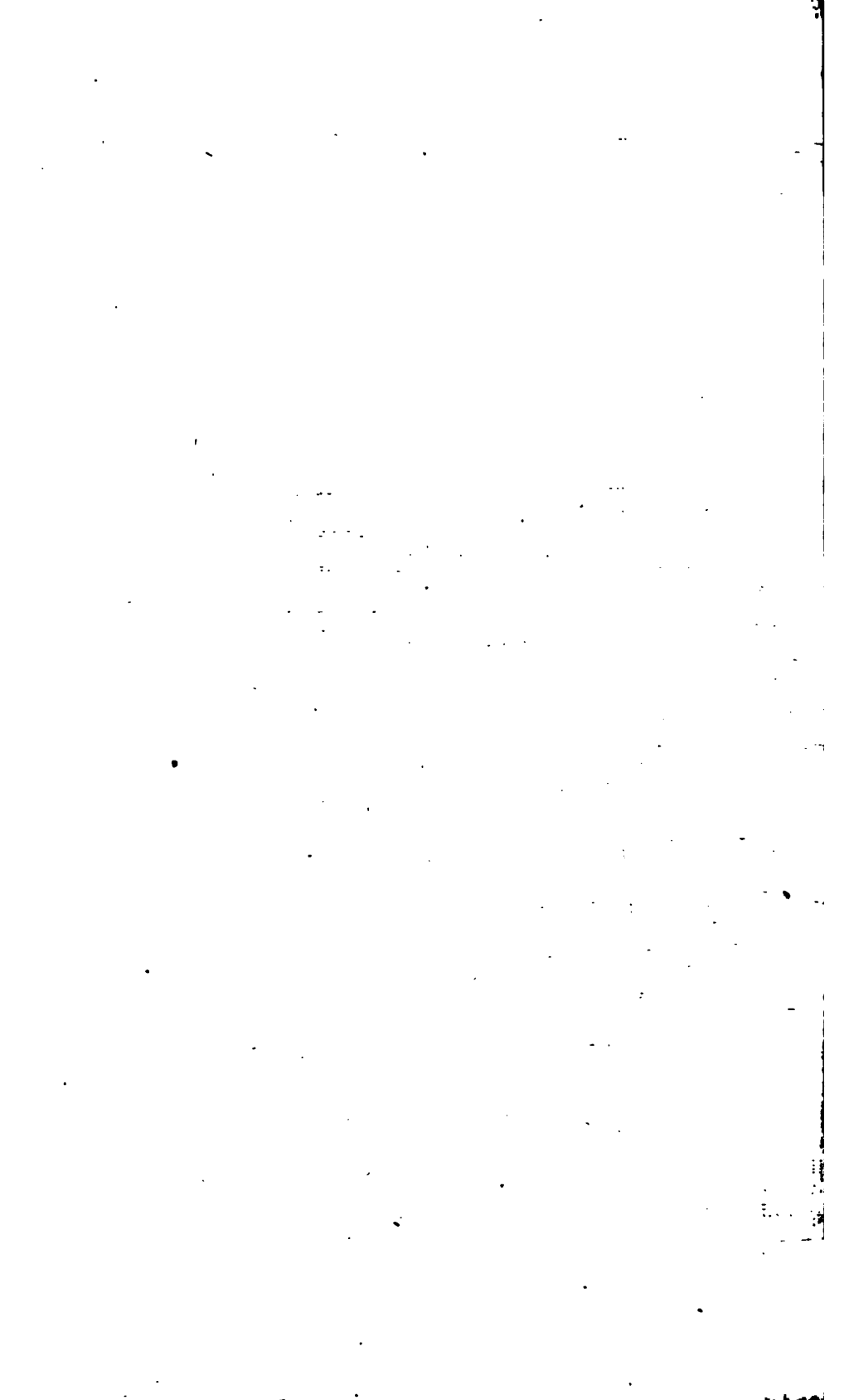
Lead wire connecting frame

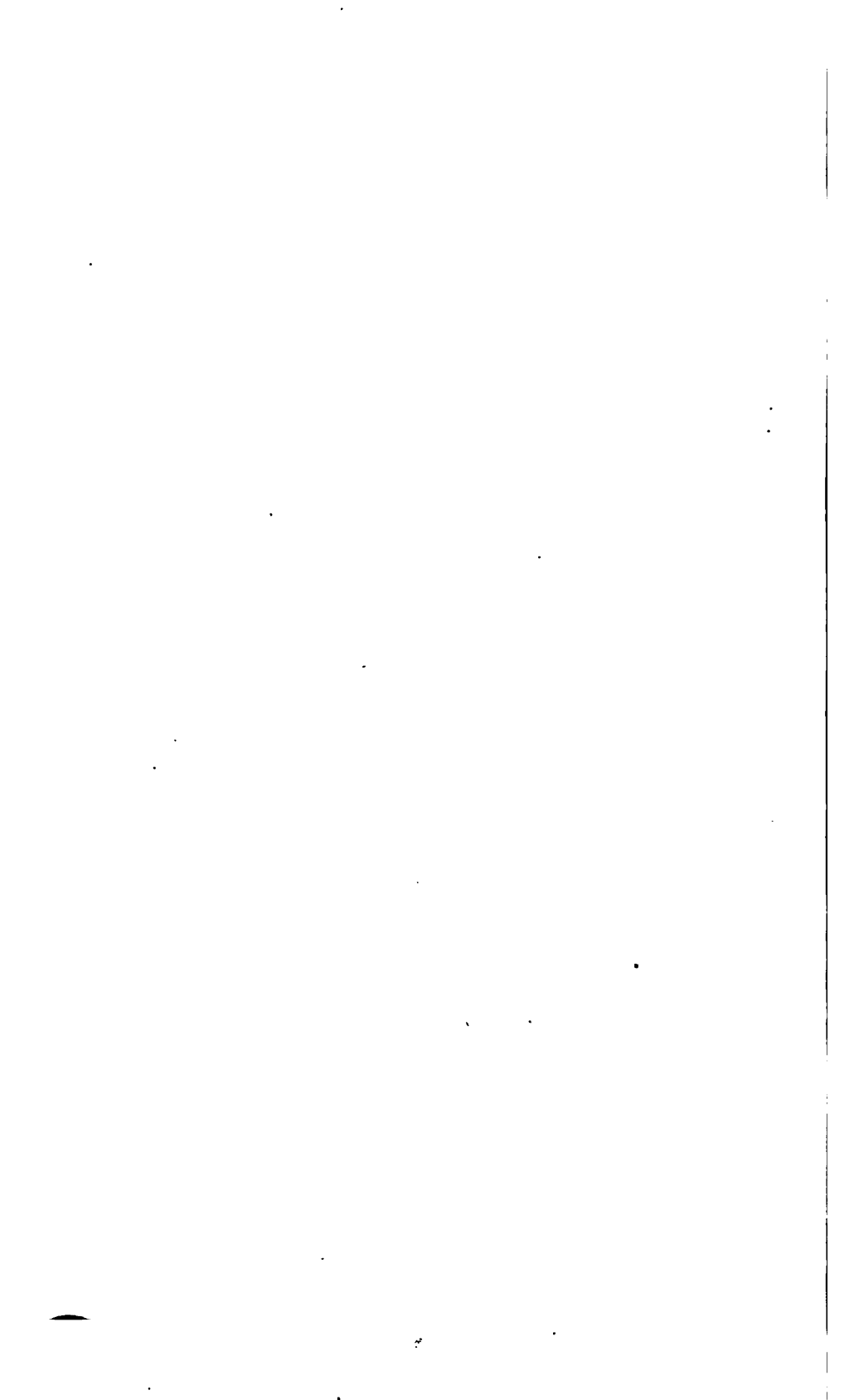
Deflagrator of two pairs



Trough represented as seen on the floor

Lead weight contained under W





APPENDIX.

CHEMICAL ANALYSIS:*

By C. U. SHEPARD, Assistant in the Chemical Department, and Lecturer on Botany, in Yale College.

It is the object of chemical analysis,† to determine the nature, proportions and mode of combination of the elements of the various compounds which occur in nature, or which are produced by art. Its importance is duly appreciated, only, when we remember that the order and regularity which it has revealed in the composition of bodies, has laid the foundation of the doctrine of chemical equivalents, and of the atomic theory; and has thus established the claim of chemistry to the character of an exact science. To be executed with success, it requires an extensive acquaintance with the physical and chemical properties of bodies, the possession of numerous pure re-agents, a variety of peculiar instruments, and much address in manipulation. It is indispensable also, that the analyst should avail himself of the experience of the great masters in the science and art of analysis, that their methods may guide him wherever analogy permits; and that he possess, of himself, a fertility of resource and invention, which may enable him to devise new processes, adapted to every possible emergency.

The elementary information, embracing, of course, a knowledge of the agents employed in chemical analysis, has already been detailed in this work; and the application of such knowledge to analytical research in aeriform substances and organized matter, has been, perhaps, so far explained in the preceding pages, as to require no farther notice in this place: it remains therefore only, that the rules for the analysis of *minerals* and *mineral waters*, be added, in order to complete the plan of these elements. The methods of investigation in these cases, require to be pointed out with more detail; since mineral substances usually form the first subjects of analysis with the young chemist, and in consequence of their numerous relations to the wants of mankind, often require to be submitted to chemical examination.

* Drawn up by Mr. Shepard, for this work, by request of the author.

† Not having room for more particular references, I wish to state, that the principal authorities for the directions contained in this essay, are, the Elements of Henry, Turner, and Murray, Children's Translation of Thénard on Analysis, Faraday on Chemical Manipulation, Ure's Dictionary, the chemical writings of Berzelius, Thomson's Memoir on Analysis in Ann. Lyc. Nat. Hist. New York, Vol. III., and several recent analyses, published in various scientific journals.—C. U. S.

I. ANALYSIS OF MINERALS.

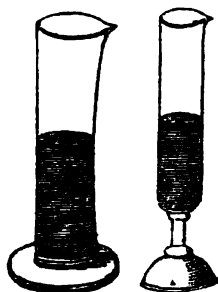
The manipulations and apparatus, requisite in the analysis of minerals, may be described under the general heads of *comminution*, *weighing*, *solution*, *evaporation*, *neutralisation*, *precipitation*, and *filtration*.

COMMINUTION.—After the substance to be analyzed, has been selected in a state of the greatest possible purity, the first step in its analysis, is to reduce it to small fragments, and generally to an impalpable powder. This is effected by mortars of steel, porphyry or agate. In pulverizing the harder stones, advantage is occasionally gained, by first igniting and then immersing them, while hot, in water. The use of the steel mortar, however, renders this procedure unnecessary; since by its means, we are enabled to reduce the hardest gems to any degree of fineness, without the risk of dispersion or loss. Where a hard mineral is pulverized in an agate mortar, it sometimes becomes necessary to take into account the matter which may be abraded from the mortar during the process. In this case, it is well to crush the mineral in the steel mortar to a tolerable degree of fineness; next to weigh out 25, 50 or 100 grs. of the powder, according to the quantity we may desire, and then finish its pulverization in a mortar of such composition, (for instance, agate) that the substance abraded may be assumed to be silica; and thus the correction may be made at the proper time, by subtracting so much weight as the mortar has lost, from the silica evolved in the analysis.

WEIGHING.—A delicate balance is indispensable in the operations of analysis. It should be capable of being turned by one-fiftieth of a grain, when loaded with 500 grs. in each pan. In its construction, it is essential that the center of motion of the beam be in a straight line; that the arms be of equal length, and that the center of gravity be in the center of motion. If possible, it is desirable that the knife edge, and the planes they turn on, be of agate. The pans, the wires which support them, and the weights, should be of platinum, on account of the unchangeableness of this metal from oxidation or corrosion, and the facility with which it is cleaned from ordinary dirt, either by slight wiping or momentary exposure to the flame of a spirit lamp. When great delicacy is required, it should be suspended in a case, in order to avoid currents of air; and it should be so arranged, that when the instrument is not in use, the pans may be supported independently of the beam. The beam itself requires to be supported by other bearings than its knife edges, lest the delicate edges of suspension be injured by constantly sustaining the weight of the beam and pans. In weighing substances that are hot, attention should be paid to the effect produced by the ascending current of air: a silver capsule, weighing 600 grains when cold, weighs less by several grains when heated by a spirit lamp, and restored in this state to the pan. Hot substances are liable, also, to occasion derangements, by causing the expansion of the arm of the beam, directly over them.

SOLUTION.—This is the next step in analysis. Its great object is to subvert the aggregation, for the attainment of which, it is vastly more effectual than mere comminution: it thus effectually prepares the compound for the exercise of chemical action; or, it goes still farther, and breaks up altogether the original affinities subsisting among the ingredients in the substance, bringing them to the condition necessary for their complete separation. If the substance is soluble in water, this fluid is employed in preference to every other. In those cases where it is insoluble in this menstruum, the strong acids often prove sufficient: the remaining instances require, as a preliminary, that the substance be fused with three, four, or more times its weight of potassa, soda, baryta or their carbonates;* after which, it becomes soluble in the acids.

The vessels required for solution are various, both as respects their form and substance. A number of test or assay glasses, varying in their capacity from one to three pints, are indispensable. The most convenient forms are those depicted in the annexed cut. Where heat is applied, flasks of flint glass, varying from one ounce to a quart in capacity, are used. A projecting ring should be formed on the neck, at the mouth, that the flask may be held safely by that part,



* The vitreous acids are also employed occasionally to induce solution.

without danger of slipping; and for this purpose, the small tongs, figured on p. 500, Vol. I, will be found highly convenient. Wedgewood's basins, from one and a half to ten inches in diameter, are also necessary; but some care is required in selecting those which are of the best material. They should resist being marked by steel, and should not be so stained by a strong acid solution of sulphate of copper, or muriate of iron, that they cannot be easily cleansed by cold water. One or two basins of pure silver, and a few platinum capsules, will often prove convenient: the latter should be from one and a half to two inches in diameter; while the silver dishes may be considerably larger. These require to be lipped, and also to be provided with a projecting tongue of metal, to serve as a handle, by which they may be held with a pair of pincers. These metallic basins are frequently used with advantage for heating bodies, either in the furnace or by the spirit lamp; and often, they may be used in place of crucibles. Where the preliminary measure of fusing a mineral with an alkali is required in order to effect its solution, a crucible of platinum or silver is needed. These are made nearly in the shape of an half egg, with the bottom a little flattened, to avoid the inconvenience of not standing by themselves. They are provided with lips and covers; and are made in sizes varying, from one inch to three and a half inches, in depth. The silver crucibles are often much larger.

EVAPORATION.—The vessels necessary for the operations under this head have been enumerated under the preceding one; they consist of flasks, and basins of earthenware, silver and platinum. If the evaporation is to be performed at temperatures under ebullition, the basin should be used, and of as flaring a form as possible; that the aqueous vapor, by the aid of the atmosphere, may be removed from the surface of the liquid as fast as it is produced. If a boiling temperature is employed in evaporation, it may be applied either in basins or flasks. The only objection to the last named vessel; is the difficulty of removing the dry results. When the basin is used, great care is necessary to prevent the ebullition from throwing out small portions of the fluid, and to guard against contamination from dirt and vapors which may be floating near by. The best protection from the effects of these evils, is a second basin put over the first and kept hot by filling it with heated sand. The solution will require to be uncovered and stirred with a glass rod, however, when the solid matter begins to be in such proportion to the liquor, as to form a thick mixture; since the free circulation which took place throughout its mass before, is now interrupted, and the steam accumulating at the bottom of the basin produces little explosions throwing the substance from the vessel in very considerable quantity. The stirring of the solution must be continued until it is evaporated to perfect dryness. In order to learn whether all the water that can be dissipated by this process has risen, a cold glass plate is held for a moment over the basin; if dimness appears, it proves that water is still rising. Where filters with precipitates upon them are to be dried, the operation may be hastened, by folding together the filter and laying it between several layers of bibulous paper, after which, it may be removed and placed upon a piece of tin plate, or within an evaporating basin; the tin plate, or the evaporating basin being moderately heated over the sand bath.

NEUTRALIZATION.—In testing for alkalies and acids in a free state, test papers are preferable to liquids. Those employed, are litmus and turmeric papers. Particular care should be taken that the papers be free from earthy matter, especially, carbonate of lime, and alkalies. Their application to liquids, to learn whether they are in a neutral state, or if not, whether the alkali or the acid be predominant, is best made by touching the edge of the paper with a rod dipped in the fluid. In this way, we waste less of the fluid, and avoid its contamination, if the paper contains soluble matters. As the proportion of free acid or alkali diminishes, the intensity of the new tint produced upon the paper is also diminished; and when, in very small quantity, it requires considerable attention before a decision can be made. The test paper should occasionally be touched with pure water in the immediate neighborhood of the part where the solution has been applied; for any change in appearance that may have occurred, not due to mere moistening, is then readily perceived.

Neutralizations are frequently aided by heat, especially, if a carbonate be used, or if precipitation occur during the operation; the carbonic acid, in the first case, is dissipated, and in the latter, the combination is more rapidly and perfectly effected. Evaporating basins are highly useful for this purpose; their contents being easily stirred, and the rod used for that purpose also, is applied to moisten the test paper when required.

PRECIPITATION.—This operation, which consists in changing substances from a soluble to an insoluble state, is of very frequent occurrence in chemical analysis. The best method of effecting it so as to secure the separation of the whole of a substance held in solution, requires, therefore, very particular notice. As to the vessels in which it should be performed, they have already been mentioned under the head of solution; the assay or test glasses, however, in consequence of their shape and transparency, are best adapted to the present purpose. When a substance in solution is to be precipitated by certain tests, the latter are to be added, and thoroughly mixed by the aid of a glass rod, with which the fluid is agitated. In some instances the precipitation ensues immediately; in others, it is requisite that the vessel should stand for several hours, and even this is not in all instances, sufficient to induce the expected precipitate; in such cases, heat must be applied, during which, or on the cooling of the solution, the precipitate will make its appearance.

It is frequently necessary to avoid adding the precipitant in excess. In such cases, the additions are made in small quantities at a time, and at intervals, in order to allow the precipitate to subside that we may discover the effect of the additions, whether they produce an increased separation, or whether the fluid remains but partially troubled or becomes transparent. Sometimes the solution contains so much of precipitable matter, that it requires dilution in order to throw down the whole of the dissolved substance.

FILTRATION.—This is usually supplementary to the last noticed operation. It consists in separating solid, from fluid substances, through which they are mechanically disseminated. In analysis, the operation is performed by two methods; the first, by causing the mixed substances to strain through unsized paper; and the second, by allowing the finely divided solid matter to subside and pouring off the clear supernatant fluid. The former of these only, should in strictness, be alluded to under the present head; the latter constituting another process, called *deccantation*; but as they both regard the same object, it is more convenient to consider them as one operation. No other vessels than the lipped test glasses, already described, several sizes of well ribbed funnels, and a variety of spatulas, are required. The greatest difficulty is in the filtering paper, which needs to be so porous as to admit the passage of fluids with freedom, while it must be so close as to retain the finest solid particles: and so free from impurities as not to contaminate the solution passing through it, or if heated with the substance retained upon it, to occasion no mixture of ashes. In order to free filtering paper of the lime which it contains, (and which comes from the bleaching of the rags by means of chloride of lime,) it is generally requisite to digest it in diluted nitric acid, and afterwards to wash it thoroughly in warm water. A number of filters of different sizes, to suit the funnels, and so made as to drop entirely within them should be kept on hand. The paper should be effectually dried over a sand bath previous to its being folded; and it should be folded double, so as make two filters in each case, as nearly as possible, of exactly the same weight,—the equilibrium between the two being nicely adjusted by cutting off little pieces with the scissors from the largest; the two filters are then placed the one within the other, and preserved in a box, away from dust and moisture.

As we must have constant regard to the washing of the precipitate collected upon the filter, in order to remove from it every trace of the original liquid, care should be taken not to accumulate the precipitate so that it shall occupy too large a space within the filter. A filter of such a size should be selected, as shall cause the precipitate to form but a thin layer over its bottom, from which it may be completely stirred up, by delivering upon it a fine jet of water from the dropping tube, or sucker, which consists of a glass tube about a foot long, terminating below in an opening almost capillary, and having a portion about three or four inches from the top, blown into a globular cavity. It is dipped into water, which by the action of the mouth is drawn in, until the globular cavity is filled. This water is then forced out, by the pressure of air within the cheeks; and the stream is directed against the bottom and sides of the filter, the effect of which, is to stir up and thoroughly wash the precipitate. The process is continued till the water which passes through, when evaporated from a silver spoon over a spirit lamp, leaves no sensible residue.

When the bulk of the precipitate is very inconsiderable, it is necessary to prevent its final accumulation upon the sides of the filter. This may be done, in part, by washing it down from the sides, by means of the dropping



tube; though it is often considerably assisted by covering the funnel with a clean basin, which protects its contents from evaporation; the effect of which always is, an ascent of currents of the fluid from below, bringing with them portions of the diffused substances, and depositing them upon the upper part of the filter. The cover should in no instance touch the filter; but merely rest upon the edge of the funnel.

When the washing is over, the filter and its contents are left upon the funnel, until they can bear handling without risk of being torn; when the remainder of the drying is effected, as described under solution. The difficulty of separating entirely the dried precipitate from the filter, in order to estimate its weight, is the reason of using double filters. As soon as the powder has become dry, its weight is ascertained by separating the filters, putting the one holding the precipitate into one scale of the balance, and the empty one into the opposite scale; and then finding what weight is requisite to place the former in equipoise. This gives the weight of the precipitate in its hydrous state; its weight in the anhydrous state is thus determined. A small platinum crucible, about an inch high, is placed in equipoise in the scales; and as much of the precipitate, as can be conveniently taken off the filter, is put into it, and its weight determined. The crucible is removed from the scale, and exposed to the flame of a spirit lamp till it becomes red hot; in which state it is kept for about ten minutes. As soon as it is cold, it is replaced in the scales; and the loss which it has sustained, determined. From this, it is easy to ascertain the loss of weight which the whole precipitate would have sustained, had it been subjected to ignition.

Decantation, in many analytical experiments, is a process much superior to that of filtration. It should be adopted, especially, where the precipitate is heavy and dense; and in all cases, where its bulk is small in proportion to that of the clear fluid above. The only objection to it, is the quantity of water which it requires, and the time it consumes; for, after having poured off the clear solution, it is necessary that the jar be filled up with water, the whole mixed by a stirrer, and the mixture left to settle as in the first case: when it becomes clear, the solution is again to be decanted and fresh water added; and the operation is to be repeated, until what is removed contains no soluble matter. To avoid losing any portions of the solution by the adhering of drops to the lip of the glass and by running down upon the outside of the vessel, it is well to touch the extremity of the lip with a little melted tallow. The syphon may often be employed to advantage in withdrawing the supernatant fluid. The precipitate may, at last, be transferred to a platinum capsule, in which, the remaining portion of water may be driven off, by the use of the sand bath, or the spirit lamp.

PRELIMINARIES IN THE ANALYSIS OF MINERALS.—THE USE OF THE BLOWPIPE.

A solid mineral substance, of whose composition we are ignorant, is in the first place to be referred to one of the following general divisions: viz. I. *Earths*; II. *Salts*; III. *Metals*; IV. *Inflammables*. The distinguishing characters of these classes are the following;

Earths.—Insoluble in less than one hundred times their weight of water; tasteless; not consumed in any considerable degree by being kept for some time on a red hot iron; specific gravity below 5.*

Salts.—Soluble in less than one hundred times their weight of water.

Metals.—Specific gravity above 5.

Inflammables.—Inflammable; destitute of metallic lustre.

Having fixed the class to which a substance to be analyzed belongs, a preliminary trial should be made to ascertain its constituent principles, independently of any attempt to learn their proportions. This is generally done by effecting a solution of the substance, and by the application to minute portions of it contained in test tubes, and assay or watch glasses, of a variety of reagents; the examination of the precipitates obtained, affords the desired information.

In these qualitative trials, however, important aid is often derived from the use of the mouth blowpipe. A large wax candle affords the best flame; and the oper-

* This class will embrace several substances which strictly speaking are salts; notwithstanding, in common language they are denominated earths, and are conveniently regarded as such for our present purpose.

ator must acquire the habit of breathing through his nostrils, and propelling the air by the muscles of the mouth so as to produce a continued current of air, and in this way to give rise to a distinct conical flame. The external apex of the flame will be red and ill defined; but within will exist a blue and well defined point of flame. The substances to be submitted to the action of the blowpipe are supported either on charcoal, a slip of platinum or on silver foil, or held in a pair of platinum forceps. The metallic supports are used only, when the subject of the experiment is intended to be exposed to the action of heat and might be liable to be altered by the action of charcoal. Salts and volatile substances, are to be heated in glass tubes, closed at one end. The three most useful fluxes, are the triple phosphate of soda and ammonia, and the sub-carbonate of soda and borax. These are kept ready pulverized, and deprived of their water of crystallization; and when used, are taken up by the moistened point of a knife,—the moisture causing the powder to cohere, and preventing it from blowing away before it enters into fusion. When melted, the substance to be examined is placed on it; and submitted first to the action of the exterior, and then to that of the interior flame. The appearances to be noticed are as follows; whether the substance be dissolved, and if so, whether with or without effervescence: the transparency and color of the bead while cooling and when cold: the nature of the glass formed by the exterior flame, and that by the interior flame; also the foregoing appearances with each of the fluxes.

Sub-carbonate of soda does not form a bead on charcoal; but with a certain degree of heat, it is absorbed: it must therefore be added in very small quantities, using a gentle heat at first, which will promote combination with the subject of experiment, if it has any affinity for this flux.

If the glass bead becomes opaque as it cools, so as to render the color indistinct, it should be broken down and a part of it mingled with more of the flux, till the color becomes more diluted, and capable of being observed. To make the color more perceptible, also, the bead may be drawn out to a thread, while hot. If it be wished to oxidate a metallic substance combined with either of the fluxes, the glass is first heated intensely, and when fused, gradually withdrawn from the point of the blue flame; and the operation is repeated, as often as necessary, using a jet of large aperture. The addition of a little nitre also assists the oxidation. For the reduction of metallic oxides, the glass bead is to be kept in fusion on charcoal, as long as it remains on the surface and is not absorbed, that the metallic particles may collect into a globule. It is then to be fused with an additional quantity of soda, which will be absorbed by the charcoal, and the spot where the absorption has taken place, strongly ignited by a tube with a small aperture. By continuing the ignition the portion of metal not previously reduced, will now be brought to the metallic state, and the process may be assisted by placing the bead in a smoky flame, so as to cover it with a soot, that is not easily blown off. When the charcoal is cold, that part impregnated with the fused mass must be taken out with a knife, and ground with distilled water in an agate mortar. The soda will be dissolved; the charcoal will float and may be poured off; and the metallic particles will remain in the water, and may be examined. In this manner most of the metals may be reduced. We shall point out the distinctive characters of some of the earths and metallic oxides and acids before the blowpipe. The matter of the candle is occasionally of serious use in reducing a metallic oxide; the fragment is covered with it, and the combustible matter aids in removing the oxygen.

1. *Earths.*

Baryta, when containing water, melts and spreads on the charcoal. Combined with sulphuric acid, it is converted in the interior flame, into a sulphuret; and is absorbed by the charcoal with effervescence, which lasts as long as it is exposed to the action of the instrument. The cold matter placed on the tongue gives the sensation of sulphuretted hydrogen.

Strontia, if combined with carbonic acid, when held in small, thin slivers with platinum forceps in the interior flame, has its carbonic acid driven off, and on the side of the fragment farthest from the lamp, a red flame is seen, sometimes edged with green, and scarcely perceptible but by the flame of a lamp.* Sulphate of strontia is

* A most intense light is emitted by carbonate of strontia which is much more difficult to melt than carbonate of baryta.

reduced in the interior flame to a sulphuret; which, dissolved in a drop of muriatic acid and diluted with alcohol, burns with a red flame.

Lime.—The carbonate is easily rendered caustic by heat; it then evolves heat on being moistened, turns paper stained with turmeric brown, and is infusible before the blowpipe. The sulphate is easily reduced to a sulphuret; and possesses, besides, the property of combining with fluor spar (when added in excess) at a moderate heat, and forming a clear glass.

Magnesia produces, like strontia, an intense brightness in the flame of the blowpipe. A drop of a solution of nitrate of cobalt being added to it, and then dried and strongly ignited, a faint flesh red color, scarcely visible by the light of a lamp, is produced. It is thus detected in compound bodies if they do not contain much metallic matter, or a quantity of alumina exceeding that of the magnesia. Some inferences as to the proportion of the magnesia may be drawn from the intensity of the color produced. The preceding earths, when pure, are readily fusible with the fluxes, into a clear, colorless glass, without effervescence; but in adding them in large proportions to the fluxes, the glasses they yield are opaque.

Alumina combines more slowly with the fluxes, than the preceding earths do, forming a clear glass, which remains transparent. Its most striking character, however, is the bright blue color it acquires from the addition of a drop of nitrate of cobalt, after having been dried and ignited for some time. It may thus be detected in compound minerals, where the metallic substances are not in great proportion, nor the quantity of magnesia large.

Lithia.—This earth may be detected even where it is present only in a very small proportion, by reducing a piece of the mineral, not larger than a pin's head, to a fine powder, and heating it to redness with an excess of carbonate of soda on a slip of platinum foil, before the blowpipe, for the space of two minutes; the stone becomes decomposed, the soda expels the lithia from its combination, and the excess of alkali becoming fluid at this temperature, spreads over the surface of the foil, and envelopes the decomposed mass; the platinum, around the fused alkaline mass, assumes a dark color, deep and extensive in proportion to the quantity of lithia present.

2. Metallic Oxides and Acids.

Arsenic flies off, when heated, with an odor resembling garlic. White arsenic gives no odor when heated alone on metallic supports; but affords the characteristic smell by being first mingled with powdered charcoal. If in a solution, it may be detected by dipping into it a piece of pure and well burnt charcoal which is afterwards to be dried and ignited.

Chromium.—The green oxide, fused with the phosphate of soda and ammonia in the interior flame, gives, at the instant of its being withdrawn, a violet hue, approaching more or less to dark blue or red, according to the proportion of chromium; after cooling, the glass is bluish green, but less blue than copper glass; in the exterior flame, the color is brighter and less blue. With borax, it forms a bright yellowish or yellow red glass in the exterior flame; and in the interior flame, this becomes darker and greener, or bluish green.

Molybdic acid melts by itself on charcoal with ebullition, and is absorbed. In a platinum spoon, it emits white fumes, and is reduced in the interior flame to molybdous acid, which is blue; but in the exterior flame, it is again oxidated and becomes white.

Tungstic acid becomes, upon charcoal, at first brownish yellow, is then reduced to a brown oxide, and lastly becomes black without melting or smoking. With phosphate of soda and ammonia, it forms, in the interior flame, a pure blue glass; in the exterior flame, the color disappears, and appears again in the interior.

Columbic acid undergoes no change by itself; but is readily fused with phosphate of soda and ammonia, and with borax, into a clear colorless glass, from which, the oxide may be precipitated by heating and cooling it alternately. This and the two foregoing acids are irreducible before the blowpipe.

Oxide of Titanium becomes yellowish when ignited in a spoon, and upon charcoal, dark brown. With phosphate of soda and ammonia, it gives, in the interior flame, a fine violet colored glass, more tending to blue than that from manganese. In the exterior flame this color disappears. With borax, it gives a dirty, hyacinth color.

Oxide of Cerium becomes reddish brown when heated. With phosphate of soda and ammonia, if heated a long time in the internal flame, it gives a clear, colorless glass.

Oxide of Uranium.—The yellow oxide, by ignition, becomes green, or greenish yellow. With phosphate of soda and ammonia, in the interior flame, it forms a clear yellow glass, the color of which become more intense when cold. With borax, in the interior flame, a clear, colorless, or faintly green glass is formed, containing black particles, which appear to be the metal, in its lowest state of oxidation. In the exterior flame, this black matter is dissolved, if the quantity be not too great, and the glass becomes bright yellowish green, and after further oxidation yellowish brown.

Oxide of Manganese gives with phosphate of soda and ammonia, in the exterior flame, a fine amethyst color, which disappears in the interior flame. When, from its combination with iron, or any other cause, it does not produce a sufficiently intense color in the glass, a little nitre may be added to it, while in a state of fusion; and the glass then becomes dark violet while hot, and reddish violet when cool.

Oxide of Tellurium, when gently heated, it becomes first yellow, then light red, and afterwards black. It melts and is absorbed by the charcoal, and is reduced with a slight detonation, a greenish flame and a smell of horse radish. It is dissolved in phosphate of soda and ammonia, without being colored.

Oxide of Antimony, is partly reduced in the exterior flame, and spreads a white smoke on the charcoal. In the interior flame, it is readily reduced, either alone, or with the addition of carbonate of soda. Sulphuret of antimony melts on charcoal, and is absorbed.

Oxide of Bismuth melts readily in a spoon to a brown glass, becoming brighter as it cools. With borax, it forms a gray glass, which decrepitates in the interior flame, and the metal is reduced and volatilized. It is, likewise readily reduced by itself, on charcoal.

Oxide of Zinc with carbonate of soda is reduced, and burns with its characteristic flame, depositing its oxide upon the charcoal. By this process it may easily be detected in minerals, when it forms but a small portion per cent. One of the most unequivocal characters of the oxide of zinc, is to dissolve it in vinegar, evaporate the solution to dryness, and to expose it to the flame of a lamp, when it will burn with its peculiar color.

Oxide of Cadmium is orange yellow, not volatile, and easily reduced.

Oxide of Iron produces with phosphate of soda and ammonia, or borax, in the exterior flame, when cold, a yellowish glass, which is blood red while hot. The protoxide forms, with these fluxes, a green glass, which, by increasing the proportion of the metal, passes through bottle green to black. The glass from the oxide becomes green in the interior flame, and is reduced to protoxide, becoming at the same time attractible by the magnet.

Oxide of Cobalt becomes black in the exterior, and gray in the interior flame; a small proportion forms, with phosphate of soda and ammonia, and with borax, a blue glass,—that with borax being the deepest. By transmitted light, the glass is reddish.

Oxide of Nickel becomes black at the extremity of the exterior flame, and in the interior, greenish gray. It is dissolved readily, and in large quantity by phosphate of soda and ammonia. The glass while hot, is of a dirty dark red, which becomes paler and yellowish as it cools. After the glass has cooled, it requires a large addition of the oxide to produce a distinct change of color. Nitre added to the lead makes it froth, and it becomes red brown at first, but afterwards paler.

Oxide of Tin, in the form of hydrate and pure, becomes yellow when heated, then red, and when approaching to ignition, black. It is very easily reduced, without addition.

Oxide of Lead melts, and is very quickly reduced, either without any addition, or when fused with phosphate of soda and ammonia, or borax.

Oxide of Copper is not altered by the exterior flame, but becomes protoxide in the interior. With both phosphate of soda and ammonia, and borax, it forms a yellow green glass while hot, but also it becomes blue green as it cools. When strongly heated in the interior flame, it loses its color, and the metal is reduced. Salts of copper, when heated before the blowpipe, give a fine green color to the flame.

Oxide of Mercury, before the blowpipe, becomes black and is entirely volatilized.

ANALYSIS OF EARTHS.

The most frequent ingredients in the compounds of this class, are silica, alumina, lime, magnesia, and the oxides of iron and manganese. They sometimes contain

the carbonic and sulphuric acids; and more rarely, glucina, yttria, zirconia, baryta, potassa, soda, and oxide of chromium. Silica and alumina, however, are the most abundant elements. It is convenient to divide them into two classes; viz. 1. minerals soluble in nitric or muriatic acids; 2. minerals which, in order to dissolve in muriatic acid, must be heated to redness, with a mixture of alkalis, or alkaline carbonates.

1. Minerals soluble in nitric or muriatic acid.

(a.) Those which dissolve with effervescence are carbonates. To determine the weight of the carbonic acid, a given weight of the carbonate is introduced into a flask, to which a spiral tube is adopted; and a sufficient quantity of dilute nitric or muriatic acid is added: when the decomposition is complete, we deduct from the sum of the weights of the flask, the acid and the salt, that of the flask, and its remaining contents;—the loss of weight is the quantity of carbonic acid. To learn the quantity of water in the carbonate, an equal weight must be exposed for half an hour to a full white heat, in a platinum crucible. The difference between the loss of weight from the ignition, and the solution, indicates, approximately, the proportion of water in the mineral. Its quantity may be ascertained more precisely, by causing the watery vapor evolved during the heating of the mineral, to pass through a weighed tube filled with fragments of the chloride of calcium (fused muriate of lime,) by which it is absorbed.

If the carbonate is marble, or pure carbonate of lime, the proportion of the base is obvious; but should carbonate of magnesia be present, the magnesia and the lime may be separated in the following manner. The solution of the mineral in muriatic acid, is evaporated to perfect dryness, and re-dissolved in a moderate quantity of water. To the solution, oxalate of ammonia is added as long as a precipitate ensues. The oxalate of lime is converted into quick lime by a white heat, and weighed; or, it may be decomposed by a red heat, and after moistening the resulting carbonate with a strong solution of carbonate of ammonia, it should be dried, heated to low redness in a platinum crucible over an alcoholic lamp, and regarded as a pure carbonate of lime. To the filtered liquid containing the magnesia, an excess of carbonate of ammonia, and then phosphate of soda is added, when the magnesia, in the form of the ammoniaco-phosphate, is precipitated. Of this precipitate heated to redness, 100 parts, according to Stromeyer, correspond to 37 of pure magnesia.

Where strontia, or baryta exist with the lime, the solution of the compound in nitric acid, is evaporated to dryness; and the residuum digested in alcohol, which dissolves the nitrate of lime, and leaves the nitrate of strontia, or baryta, undissolved.* The solutions are evaporated to dryness, and the nitrates decomposed by heat.

Strontia and baryta are separated from each other in consequence of the solubility of the muriate of the former, and the insolubility of the muriate of the latter in alcohol. In order to render the separation complete, M. Kastner remarks, that the salts must be rendered anhydrous, and the alcohol with which it is treated, heated to 138° Fah., care being taken that the alcohol is guarded, so that it cannot attract water from the atmosphere.

(b.) A large number of minerals, consisting of various hydrous silicates, such as silicates of alumina, of lime, of iron, of potassa, or of soda, united together in different proportions, are readily soluble in muriatic acid, unattended by any effervescence. These substances require to be rendered perfectly impalpable. The quantity employed for analysis, may vary from 25 to 50 grains. The proportion of water, if any is present, is ascertained by heating the mineral to whiteness for half an hour, and observing the loss of weight in the crucible when cold. It is then transferred to a flask, and digested on the sand bath with diluted muriatic acid, till a solution is ob-

* For the detection of baryta or strontia when in union with lime, the solution of the mineral in nitric acid should be evaporated to dryness, and the nitrates decomposed by heat. Upon the dry mass, water is boiled for a few minutes, keeping the crucible at the same time loosely covered with its lid. The whole is thrown on a covered filter; and to the liquid which passes through, sulphuric acid, or a soluble sulphate is added: a white precipitate will appear, if either baryta or strontia be present; but if not, the liquid will retain its transparency. (Ph. Mag. and An. Ph. 1830, Vol. vii, p. 404.)

tained; observing the precaution to agitate the vessel almost constantly during the operation, to prevent any of the silica in the mineral from adhering to the inside of the flask. Immediately on its solution, the contents of the flask are to be poured into an open evaporating dish, before the silica begins to gelatinize.*

The acid solution is evaporated to dryness; and water, acidulated with muriatic acid, is digested on the dry residue, till every thing is taken up except the silica, which has now become insoluble. The whole is then carefully washed into a (double) filter. The silica, washed clear, is dried, ignited, and weighed.

The liquid which has passed through the filter, may contain alumina, lime, oxide of iron, and a fixed alkali. It is reduced by evaporation to so small a quantity, as to be operated upon with convenience. Caustic ammonia is added in excess, which precipitates the alumina and iron, while the lime and the fixed alkali remain in solution. The precipitate is collected as before, and its weight determined. Let it = a . It is put into a flask, and digested in muriatic acid, until dissolved. A few white flocks of silica commonly remain. They are collected,edulcorated, ignited and washed; and their weight added to that of the silica already found, and deducted from the weight of a , which indicates the alumina and oxide of iron in the mineral. To the muriatic solution, previously rendered nearly neutral by evaporation, a large excess of dilute solution of potash is added; and the mixture is boiled for some time in a flask. The alumina is dissolved; while the per-oxide of iron remains behind in the state of red flocks. The iron is collected on a filter, heated and weighed. Let its weight = b . It is obvious that the alumina = $a - b$.

Sometimes manganese is also present in the liquid, as well as iron. In such cases the precipitated per-oxide of iron (if the foregoing process be adopted) will contain the manganese.† To separate the manganese from the iron, the easiest way is to dissolve the mixture in muriatic acid, and to pour into the solution, rendered as neutral as possible by concentration, a solution of chloride of lime; the manganese falls in the state of a red powder. Afteredulcoration and ignition, 6 of this matter is equal to 4.5 protoxide, or to 5 deutoxide of manganese. This amount being deducted from the original weight of the mixture of iron and manganese, will leave the weight of the per-oxide of iron contained in the mineral.‡

* Should any portions of the silica adhere to the inside of the flask, a little potash ley, assisted by a gentle heat, will readily dissolve it. But care must be taken not to act upon the glass flask.

† The presence of manganese is easily detected by a solution of chloride of lime, a drop of which let fall into a liquid containing manganese, will immediately produce a red precipitate in flocks.

‡ To separate the oxides of iron and manganese, a great variety of methods have been proposed. A very easy one seems to be, to throw down the oxides (the iron being per-oxidized) together from their solution; to wash them by decantation; and to digest them in muriate of ammonia with a little sugar. The manganese, both protoxide and per-oxide, will be dissolved, and the oxide of iron will remain. If the iron is in large proportion, compared with the manganese, the following process may be adopted with advantage: To the cold solution, considerably diluted with water, and acidulated with muriatic acid, carbonate of soda is gradually added, and the liquid is briskly stirred with a glass rod during the effervescence, in order that it may become highly charged with carbonic acid. By neutralizing the solution in this manner, it at length attains a point at which the per-oxide of iron is entirely deposited, leaving the liquid colorless; while the manganese, by aid of the free carbonic acid, is kept in solution. The iron, after filtering, is collected on a filter, and its quantity determined in the usual manner. The filtered liquid is then boiled with an excess of the carbonate of soda; and the precipitated carbonate of manganese is collected, heated to full redness in an open crucible, by which it is converted into the red oxide, and weighed. This method is one of some delicacy, but in skilful hands it affords a very accurate result. It may also be employed for separating iron from magnesia and lime, as well as from manganese. But if the proportion of iron is small, compared with that of manganese, the best mode of separating it, is by succinate of ammonia or soda, prepared by neutralizing a solution of succinic acid with either of these alkalies. That this process should succeed, it is necessary that the iron be wholly in the state of the per-oxide, that the solution be

The liquid thus freed from alumina, iron, and manganese, still contains lime and a fixed alkali. It is to be heated, and oxalate of ammonia added to it as long as any precipitate falls. Let this precipitate be treated as directed on page 9.

To obtain the alkali, evaporate the liquid thus freed from lime, to dryness; and heat the residual salt in a platinum crucible, (taking care not to fuse it) till all ammoniacal fumes are dissipated: what remains is an alkaline chloride. To determine its nature, dissolve it in a little water, and add to the solution some muriate of platinum. If the alkali be potash, a yellow precipitate will fall; but none will appear if the alkali be soda: $\frac{6}{9.5}$, or $\frac{1}{1.5}$ ths of the weight, indicates the quantity of potash, if the salt was a chloride of potassium; $\frac{4}{7.5}$, or $\frac{1}{1.8}$ ths of the weight, is the quantity of soda contained in chloride of sodium.*

2. Minerals not soluble in nitric or muriatic acid.

These are usually rendered soluble by being heated with three times their weight of dry potash or soda, or with, from three, to five parts of the carbonates of these alkalies. Minerals, in which silica, lime and magnesia, are most abundant, are usually treated with the carbonates. Either carbonate of potash, or carbonate of soda, may be used at pleasure. The carbonate of soda is most employed, from its cheapness, and the ease with which it is obtained in a state of purity. The mineral reduced to an impalpable powder, is intimately mingled in a determinate quantity (say 50 or 100 grs.), with three or four times its weight of dry carbonate of soda; and exposed in a platinum crucible, to a red heat for about half an hour, during which, the mixture is commonly fused, though this is not always indispensable. Dilute muriatic acid is added in successive portions, to detach the contents of the crucible. If the mineral has been sufficiently acted upon by the alkali in the operation, the solution will be complete, or a few, light, white flocks only, will remain undissolved; whereas, when the powder has not been thoroughly decomposed, it remains in the condition of a dense mass, at the bottom of the dish; in which case, it will require farther pulverization, and a renewed heating, with a new portion of carbonate of soda. It has been observed by Berthier, that in the case of highly siliceous minerals, a mixture of five parts of carbonate of potash, and four parts of carbonate of soda, requires much less heat for breaking up their original composition, and rendering them soluble. A spirit lamp is sufficient to render two or three hundred grains of the compound perfectly liquid. In the cases where the hydrated alkalies are employed, the mixture is put into a silver, instead of a platinum crucible, which is corroded by pure alkalies; and this is placed in one of earthen ware, the interstices being filled with sand. A little water is added at first, to dissolve the alkali: the mixture is stirred with a silver rod carefully, as the heat increases, and is pressed down, to prevent it from swelling over the sides of the vessel. As soon as the moisture is dissipated, the lid of the crucible is put on, and the heat is allowed to increase to low redness, at which point it is maintained for half an hour. The crucible being removed from the fire, is well cleaned on the outside, and placed, with its contents, in a Wedgewood basin, where it is to be thoroughly drenched with hot water, till the whole mass is detached. The crucible is removed, and muriatic acid added. If a portion

exactly neutral, (which may easily be insured by the cautious use of ammonia,) and that the reddish brown colored succinate of iron be washed with cold water. Of this succinate, well dried, at a temperature of 212° Fahr., 90 parts correspond to 40 of the per-oxide. From the filtered liquid, the manganese may be precipitated at a boiling temperature by carbonate of soda, and its quantity determined in the way above mentioned. The benzoate may be substituted for the succinate of ammonia in the preceding process. It may be stated as a general rule, that whenever it is intended to precipitate iron by means of the alkalies, the succinates, or benzoates, it is essential that this metal be in the maximum of oxidation. It is easily brought into this state by digestion with a little nitric acid.

* Chloride of potassium, and chloride of sodium, are permanent in the air; but chloride of lithium deliquesces.

of the mineral remains undecomposed, it will require to be treated again with the alkali, as in the first instance.*

Let us suppose a mineral to be composed of silica, alumina, lime, magnesia, and oxide of iron, that it has been treated with carbonate of soda, dissolved in muriatic acid, the acid solution evaporated to dryness, and the residue digested in water acidulated with muriatic acid, by which means every thing is dissolved except the silica. The liquid containing the lime, magnesia, alumina, and oxide of iron is dissolved in an excess of muriatic acid, and put into an assay glass, furnished with a plate of glass to cover its top: into this is poured (by small portions at a time,) a solution of bi-carbonate of potash, or bi-carbonate of ammonia. After each addition a violent effervescence takes place; and the glass plate must be put over the mouth of the vessel to prevent the loss, which might be occasioned by the little drops of liquid thrown out of the glass during effervescence. This addition is to be continued till the liquid is supersaturated with the bi-carbonate. The alumina and oxide of iron are precipitated; but the lime and magnesia remain in solution, in the state of compound salts, or bi-carbonates. The precipitated alumina and oxide of iron are to be treated, for their separation, as on page 10. The liquid, containing the lime and magnesia, is saturated with muriatic acid, a little caustic ammonia added; and then the lime is precipitated by oxalate of ammonia. To obtain the lime in a separate state, the oxalate of lime is treated as on page 9. The liquid thus freed from lime is to be made boiling hot; and while in that state, mingled with an excess of carbonate of soda. After being boiled for two hours on the sand bath, the precipitated carbonate of magnesia is separated by the filter. The liquid which has passed through the filter is evaporated to dryness, and the residual salt redissolved in water; a little carbonate of magnesia will remain. The whole of the magnesia thus obtained, is to be put into a platinum crucible and exposed to a strong red heat, which expels the carbonic acid.

When we have manganese present in addition to the ingredients supposed in the last case, the following process may be advantageously adopted. The iron and alumina are separated as before, and the manganese, lime and magnesia, left in solution. If the quantity of the manganese be proportionally small, it is precipitated as a sulphuret, by the hydro-sulphuret of ammonia or potassa. This sulphuret is then dissolved in muriatic acid, and the manganese thrown down as usual by means of an alkali. But if the manganese be the chief ingredient, the best method is to pre-

* The appearances presented during these operations, afford very useful indications of the nature of the mineral under examination, and are, therefore, not to be overlooked in the preliminary trials, or qualitative analysis. If the mixture undergoes a perfectly liquid fusion, we may presume that the stone contains much siliceous earth: if it remain pasty and opaque, the other earths are to be suspected; and lastly, if it have the form of a dry powder, the bulk of which has considerably increased, it is a sign of the predominance of alumina. If the fused mass have a dark green or brownish color, the presence of oxide of iron is announced; a bright green indicates manganese, especially if the color be imparted to water; and a yellowish green, the oxide of chrome: when the muriatic solution assumes a purplish red color, it is a sign of oxide of manganese; an orange red shows iron, and a gold-yellow, chrome. Freedom from color, indicates the absence of metallic ingredients.

To discover whether any, and what acids, are contained in the mineral, to the liquor remaining after the separation of the silica, (which is effected as described on page 10,) carbonate of potassa is added, and the precipitate separated as usual. The supernatant liquid is neutralized by muriatic acid, and filtered. To discover sulphuric acid, muriate of baryta is added. Should a copious precipitate appear, which is insoluble in diluted muriatic acid, the presence of sulphuric acid is detected. If a precipitate takes place, which is soluble in muriatic acid, and without effervescence, it proves the existence of phosphoric acid; and if lime be also found, the phosphate of lime is indicated. To learn whether fluoric acid be present,—to a portion of the liquor, a solution of muriate of lime is added, till the precipitate, if any, ceases. Upon the precipitate, washed and dried, is poured a little sulphuric acid: if acid fumes arise, the acid in question may be suspected. To ascertain its presence decisively, a portion of the precipitate is distilled with half its weight of sulphuric acid. The fluoric acid will be known by its effects on the retort, and by its other properties.

cipitate it at once, together with the two earths, by a fixed alkaline carbonate at a boiling temperature. The precipitate, after being exposed to a low red heat and weighed, is put into cold water acidulated with a drop or two of nitric acid, when the lime and magnesia will be slowly dissolved with effervescence. Should a very little of the manganese be likewise taken up, it may easily be thrown down by the hydro-sulphuret of ammonia.

Separation of the oxides of chrome, iron and nickel. The oxide of chrome may be separated from those of iron and nickel, by repeatedly boiling the three to dryness with nitric acid. This will acidify the chrome, and will render it soluble in pure potassa, which does not take up the other oxides. From this combination with potassa, the chromic oxide may be detached by adding muriatic acid and evaporating the liquor till it assumes a green color. Then on adding a solution of pure potassa, the oxide of chrome will fall down, because the quantity of oxygen, required for its acidification, has been detached by the muriatic acid. The oxides of iron and nickel are next to be dissolved in muriatic acid, and the solution evaporated to dryness. Liquid ammonia is then to be added, which acts on the oxide of nickel only. The solution may be again evaporated to dryness, which will render the oxide of iron more dense, and more easily separable from the soluble portion. A fresh addition of ammonia will now readily dissolve the nickel, leaving the oxide of iron, which must be dried as usual. The oxide of nickel remains dissolved by the excess of ammonia, to which it imparts a blue color. It may be separated by evaporating the solution to dryness and dissolving the salt.

Separation of glucina and zirconia from alumina.—When alumina and glucina are present in a mineral, they may be separated from their mixed state as precipitated together, by pure potassa, which dissolves both these earths. A sufficient quantity of acid is then to be added to saturate the alkali, and carbonate of ammonia poured in, till a considerable excess of this carbonate is manifested by the smell. The alumina is thus separated, but the glucina, being soluble in the carbonate of ammonia, remains dissolved and may be precipitated by boiling the solution. Zirconia is separated from alumina by boiling the mixed earths with pure soda, which acts only on the latter; or from an acid solution containing both earths, the alumina is thrown down by saturated carbonate of potassa, which, when added in excess, re-dissolves the zirconia. Glucina and zirconia, or glucina and yttria, may be separated, when mixed together in solution, by ferro-cyanate of potassa, which has no action on glucina, but precipitates the two other earths.

In those minerals which contains a fixed alkali, such as potassa or soda, it is necessary to abstain from the use of these reagents in effecting their solution.* The other constituents of such minerals should be ascertained by the methods already described: to obtain the alkali, either of the following methods may be adopted. (1.) Twenty five or thirty grains of the mineral are intimately mingled in a platinum crucible with a quantity of powdered fluor-spar, equal in weight to two and a half times the weight of the silica contained in the mineral; this mixture is drenched with sulphuric acid, and exposed for several hours to the heat of a sand-bath. After all evolu-

* The presence of potassa in a mineral may often be detected by boiling it in powder with sulphuric acid, the acid being strong, and the digestion repeated a number of times. The residuary mass after the final boiling is washed with water; a slight excess of acid is added and the solution evaporated to a smaller bulk. If crystals of alum make their appearance, it is the indication of potassa. But since a mineral may contain potassa and little or no alumina, in which case no crystals of alum will appear, it may be necessary to add a little alumina along with the sulphuric acid. Or, the stone may be so hard as to resist the action of sulphuric acid: it will then be necessary to fuse it with soda, to dissolve the fused mass in water and to supersaturate the solution with sulphuric acid. On evaporating to dryness, and redissolving in water, the silica is separated. The supernatant fluid will first afford crystals of sulphate of soda, and afterwards of sulphate of potassa, should the latter alkali be contained in the mineral. Soda may be detected in a mineral where it exists, by treating its powder with sulphuric acid, washing off the solution, and adding caustic ammonia till the precipitation ceases. The supernatant fluid is evaporated to dryness, and the residuum heated to expel the sulphate of ammonia. The sulphate of soda will remain, and may be known by its appropriate characters.

tion of fluosilicic acid is at an end, the crucible is exposed to a red heat for half an hour, to drive off all excess of sulphuric acid and to ensure a total decomposition of the fluor-spar. The dry mass is now digested in distilled water, till every thing soluble is taken up: the solution after being mingled with a solution of carbonate of ammonia, to throw down any time that may be taken up in the state of sulphate, and filtered, is evaporated to dryness and heated to redness. What remains is the alkali of the mineral united to sulphuric acid. It is easy from the properties of the salts, to decide whether it be sulphate of soda, or sulphate of potassa, and the known constitution of these salts, enables us at once to decide the weight of alkali which the mineral contains.* (2.) The other process consists, in intimately mingling the mineral with six times its weight of the artificial carbonate of baryta, and exposing it for an hour in a platinum crucible to a white heat. The ignited mass is dissolved in dilute muriatic acid, and the solution evaporated to dryness. The soluble parts are taken up in hot water; an excess of the carbonate of ammonia is added; and the insoluble matters, consisting of silica, carbonate of baryta, and all the constituents of the mineral, excepting the fixed alkali, are collected on a filter. The clear solution is evaporated to dryness in a Wedgewood basin or capsule, and the dry mass is heated to redness in a crucible of platinum, in order to expel the salts of ammonia. The residue is the chloride of potassium or sodium. In this process, it generally happens that traces of manganese and sometimes of iron, escape precipitation in the first part of the process; in which case, they require to be thrown down by hydro-sulphuret of ammonia. If neither lime nor magnesia is present, the alumina, iron, and manganese may be separated by pure ammonia, and the baryta subsequently removed by the carbonate of that alkali. By this method, the carbonate of baryta is recovered in a pure state, and may be reserved for another analysis. The baryta may also be thrown down as a sulphate by sulphuric acid, in which case the soda or potassa is procured in combination with that acid.†

It should be observed before concluding the notice of minerals insoluble in nitric and muriatic acids, that the sulphates of baryta, strontia, and lime (as well as the fluates and phosphates of lime) are capable of an easier decomposition than that above described. Instead of fusion with alkali, they only require to be digested for one or two hours with three or four times their weight of carbonate of soda or potassa, and a sufficient quantity of water. The acid united with the earth will quit it, and pass to the potassa or soda, while the carbonic acid will leave the alkali and combine with the earth. We shall obtain, therefore, a compound of the acid of the stone with potassa or soda, which will remain in solution, while the carbonated earths will form an insoluble precipitate. But as the decomposition is liable to be incomplete, it is necessary to decant the alkaline liquor, to edulcorate the precipitate with water; then to dissolve the earthy carbonates with diluted nitric or muriatic acids, and to treat the portion which resists solution with a fresh quantity of carbonated alkali.‡ Of these compounds, the sulphate of lime is best suited to the present method. It needs only to be boiled fifteen or twenty minutes with a solution of twice its weight of carbonate of soda. The carbonate of lime after being thoroughly washed, is either heated to low redness to expel the water, and weighed, or at

* If the mineral contain magnesia, a portion of this earth in the state of sulphate, may be mixed with the alkaline sulphate. A good red heat will decompose this salt, and the magnesia will remain when the alkaline sulphate is dissolved in water.

† This mode of analysis is attended with considerable inconvenience when magnesia happens to be present, because, this earth is not completely precipitated either by ammonia, or its carbonate; and therefore some of it remains with the fixed alkali. The best mode to effect its separation, perhaps, is to add, first, carbonate of ammonia to the liquid, and then phosphoric acid; the latter, drop by drop, until all the magnesia is thrown down in the form of ammoniaco-magnesian phosphate. The excess of phosphoric acid is afterwards removed by acetate of lead, and that of lead by sulphuretted hydrogen. The acetate of the alkali is then brought to dryness, ignited, and, by the addition of sulphate of ammonia, converted into a sulphate.

‡ This method is better adapted to the decomposition of sulphate of lime, than to that of the sulphate of baryta or strontia. The latter salts are better decomposed by being mingled with three times their weight of carbonate of soda, and heated to redness in a platinum crucible for the space of an hour.

once reduced to quick lime by a white heat. Of the dry carbonate, fifty parts correspond to twenty eight of lime. The alkaline solution is acidulated with muriatic acid, and the sulphuric acid thrown down by muriate of baryta. From the sulphate of this earth, collected and dried at a red heat, the quantity of the acid may easily be estimated.

ANALYSIS OF SALTS.

(a.) Method of determining the constituents of a salt.

Having made some preliminary trial of the degree of solubility, possessed by the salt to be subjected to examination, 50, or 100 grains, in the state of a fine and dry powder, is dissolved in a convenient quantity of water at the temperature of 120° or 130°. The solution may be made in a flask, and aided by repeated agitation from shaking; or, in those cases where the solution is more easily effected, it may be made in an evaporating basin. When the solution is complete, it is slowly evaporated, till a pellicle appears at the surface, and left to cool gradually. When cold, crystals will probably appear, which furnish a certain indication of the nature of the crystalline body, and may supersede a decomposition of the substance under examination. But as several different salts may be present in the same solution, and may not crystallize in a sufficiently distinct shape, it may be necessary to have recourse to the evidence of tests. In pursuing these investigations, it will be convenient to refer all salts to one of the following orders. (1.) *Salts with excess of acid.*—These are known by their effect on vegetable blues. (2.) *Alkaline salts.*—These are characterized by their effects on vegetable colors. (3.) *Salts with metallic bases.*—Metallic salts afford a very copious, and generally a colored precipitate, when mixed with a solution of ferro-cyanate of potassa. (See table, at the close of this essay.) To ascertain the species of metal, precipitate the whole by the ferro-cyanate of potassa; calcine the precipitate, and proceed according to the rules which are given for separating the metals, under the heads of analysis of earths, and analysis of metals. (4.) *Salts with earthy bases.*—If a solution of salt, in which ferro-cyanate of potassa occasions no precipitation, afford a precipitate, immediately, on adding pure or carbonated potassa, we may infer, that a compound of an acid, with some one of the earths, is present in the solution. Or, after ferro-cyanate of potassa has ceased to throw down a sediment, if the above mentioned alkali precipitates a farther portion, we may infer, that both earths and metallic salts, are contained in the solution. In the first case, the alkaline solution is added, until it ceases to produce a precipitate. The sediment, consisting of earths, is separated, washed and dried; and examined, according to the rules, given under analysis of earths. In the second case, ferro-cyanate of potassa is added, as long as it precipitates any thing, and the liquor decanted from the sediment, which is washed, and the washings added to what has been poured off. The decanted solution is next mixed with the alkaline one, and the precipitated earths reserved for experiment. (5.) *Neutral salts, with alkaline bases.*—These salts are not precipitated, either by ferro-cyanate, or by carbonate of potassa. It may happen, however, that salts of this class may be contained in a solution, along with metallic, or earthy ones. In this case, the metals are precipitated by ferro-cyanate of ammonia, and the earths by carbonate of ammonia, in a temperature of 180° or upwards, in order to ensure the decomposition of magnesian salts, which this carbonate does not effect in the cold. The supernatant liquid is separated by filtration, and boiled to dryness. The residuum is then exposed to a heat, sufficient to expel the ammoniacal salts.* Those, with bases of fixed alkali, will remain unvolatilized. By the present process, it will be impossible to ascertain whether ammoniacal salts were originally present; but this may be learned, by adding to the salt under examination, before its solution in water, some potassa, which, if ammonia be contained in the salt, will produce the peculiar smell of that alkali. The vegetable and mineral alkalies may be distinguished, by adding to the solution a little tartaric acid, which precipitates the former, but not the latter; or, by muriate of platinum, which acts only on the vegetable alkali. Hav-

* This application of heat will drive off, also, any excess of the ammoniacal carbonate, which might have retained in solution, either yttria, glucina, or zirconia. The alkaline salts may be separated from these earths, by boiling the mixture in water, filtering, and evaporating.

ing ascertained the basis of the salt, the acid will be easily discriminated. Muriate of baryta will indicate sulphuric acid; nitrate of silver the muriatic; and salts, containing nitric acid, may be known by a detonation ensuing on projecting them, mixed with powdered charcoal, into a red-hot crucible.

(b.) *Method of determining the proportions of the elements of salts.*

Salts are analyzed by two processes: one is the direct combination of their constituent principles, or synthesis; the other by separating their elements, or analysis. By the first of these methods, let the salt, the proportion of whose elements is to be determined, be sulphate of ammonia; we take two weak solutions, one of the acid, the other of the alkali, containing known quantities of real acid and alkali, and we ascertain, by adding the alkali cautiously to the acid, how much of it is necessary to neutralize 2000 or 3000 grains of the acid. And in a case where the elements are gaseous, as in muriate of ammonia, we measure a certain volume of the acid gas over mercury, and pass ammoniacal gas to it by degrees, till the whole of the acid is absorbed; by which, the proportion in which the two gases combine is easily determined, and from it, and their specific gravities, may be calculated the weight of acid and base in the salt. By the reverse process, if the salt be not decomposable by heat, it is calcined to redness; otherwise it is dried by exposure to the temperature of boiling water, or by placing it on hot sand in a vacuum, near a substance having a strong attraction for water. Most of the oxides are insoluble in water, and may be separated from their acid by the alkalies, provided that the oxide be not soluble in excess of alkali, nor capable of absorbing carbonic acid, or at least that it part with it again by heat, without undergoing any other change. As most oxides are insoluble in water, so, on the other hand, nearly all the acids are soluble in that fluid; consequently very few acids of salts can be isolated by precipitation. There are very few acids, however, which do not form with some base, and few bases which do not form with some acid, an insoluble salt; upon which fact very many salts are conveniently analyzed. Sulphate of soda and muriate of baryta may be quoted as examples. A certain quantity of either salt is dissolved in water, to which a solution of the other is added in excess; a precipitate of sulphate of baryta will be obtained, containing in one case all the acid of the sulphate, in the other all the baryta of the muriate. The precipitate is collected, washed, dried and ignited. One hundred parts of sulphate of baryta contains 34 of sulphuric acid, and 66 of baryta. If the oxide which forms the base of the salt to be analyzed, be fixed, and undergoes no change at a high temperature, or such only as can be taken account of, and the acid and its elements be volatile, the quantity of the former may be known, by simply calcining the salt in a platinum crucible. The oxides and acids of the greatest part of the nitrates and carbonates may be analyzed in this way. To ascertain the water of crystallization, if the salt be not decomposed at a high temperature, it is necessary only to heat a given weight to redness in a platinum crucible, and to observe how much it loses by the operation. If a high temperature would decompose the salt, destroying or volatilizing one of its constituents, 50 grains of it may be put into a very small retort, to which is fitted a receiver containing a saturated solution of potassa,—the retort and receiver being accurately weighed before the experiment begins. Heat is then gradually applied to the bottom of the retort, till the salt becomes visibly red hot. The whole is then weighed a second time. The loss of weight sustained by the retort is equivalent to the weight of the base of the salt, and to that of the water of crystallization which the salt contained. The receiver will have increased in weight, and the increase will be just equal to the water of crystallization of the salt.*

ANALYSIS OF METALS.

The diversity of metallic ores is so great as to render it impossible to give any general formula for their analysis. The limits of the present work, enable us, only to subjoin under this head a short account of the best mode of analyzing the most important ores of those metals which are most frequently presented to the chemist for his examination.

(a.) *Ores of Gold.*—Native gold is dissolved in nitro-muriatic acid; the silver, if any be present, falls to the bottom in the state of a muriate, and may be separated by

* For the method of determining the water of crystallization in those salts incapable of resisting the action of a red heat, see Supplement Encyc. Brit. Vol. III. p. 506, or Thénard on Chemical Analysis, translated by Children, p. 211.

filtration, and weighed. Proto-sulphate of iron is added to the solution, which throws down the gold in the metallic state. If copper is present, it may be precipitated by means of a plate of iron. The auriferous pyrites may be treated with dilute nitrous acid, which dissolves the iron, and separates the sulphur: the gold remains insoluble, and is found in the state of small grains. When gold and platinum are both contained in the same solution, they may be separated from each other by a solution of muriate of ammonia, which throws down the platinum, but not the gold. In this way platinum* may be detached from other metals.

(b.) *Ores of Silver.*—Native silver is dissolved in nitric acid. The gold, if the ore contains any, will remain in the state of a black powder, and may be dried and weighed. The silver is precipitated by a solution of common salt. Every 100 parts of the precipitate, washed, dried and ignited, will contain 75.5 of silver. The copper (whose presence is ascertained by the deep blue color communicated to the solution by ammonia,) is precipitated by a plate of iron. When lead is present in the solution, which is also thrown down by common salt, the silver is precipitated by a polished piece of copper. If the ore contains arsenic, that metal becomes acidified by nitric acid; and after the separation of the silver, the arsenic acid is thrown down by nitrate of lead. Sulphate of silver is treated with diluted nitric acid, which dissolves the silver and leaves the greater part of the sulphur untouched. The residuum is dried, and the sulphur burnt off; the loss of weight gives the sulphur. The silver is to be precipitated by common salt; and the other metals, if any be present, are to be ascertained as above. Part of the sulphur is always acidified. The acid thus formed, is precipitated by nitrate of baryta; 100 parts of the dried precipitate, equalling 14.5 of sulphur.†

(c.) *Ores of Copper.*—Native copper sometimes contains gold, silver, or iron. It is therefore dissolved in nitric acid; the gold remains in the state of a blackish, or rather, violet colored powder: the silver is separated by a polished plate of copper, (or it may be precipitated from a separate portion of the solution by common salt;) and the iron is separated by boiling the solution to dryness, and treating the residuum with water. By this process, the nitrate of iron is decomposed; the oxide of iron remains, while the water dissolves the nitrate of copper. This last salt is decomposed by boiling it with potash; the precipitate dried in a red heat, is black oxide of copper. 100 parts of it = 80 of metallic copper. Sulphuret of copper is dissolved in muriatic acid by the help of nitric acid. Part of the sulphur separates, while a part is acidified. The solution being divided into two parts; from the one, the copper is precipitated by an iron plate, and from the other, the iron by ammonia. Arseniate of copper is dissolved in diluted nitric acid, and nitrate of lead added to the solution, which is evaporated till a precipitate begins to appear, and then mixed with alcohol. Arseniate of lead is precipitated; 100 parts of which = 83 of arsenic acid. The copper is separated from the nitric acid, by boiling it with potash.‡

(d.) *Ores of Iron.*—Iron pyrites is treated repeatedly with boiling nitric acid till the sulphur is acidified. Muriatic acid is then added, and the digestion continued till the whole is dissolved.§ Muriate of baryta is added to precipitate the sulphuric acid. If the solution contains only iron, it is precipitated by carbonate of soda; but if earths, or manganese be present, we must proceed by the rules given under analysis of earths. When the oxides of iron are free from earthy ingredients and other metals, they are analyzed simply by dissolving them in muriatic acid, and precipitating them as above.¶

(e.) *Ores of Tin.*—The presence of tin in an ore is indicated by a purple precipitate, on mixing its solution in muriatic acid, with one of gold, in nitro-muriatic

* Hydriodic acid is a most delicate test of platinum.—See p. 372 of this Vol.

† For examples of the analysis of other ores of silver, see Klaproth, Vol. i. p. 554 et seq.; and Bonsdorff, in the Ann. of Phil. N. S. viii. p. 29.

‡ For farther information on the analysis of copper ores, see Vauquelin's remarks in Thomson's Annals, Vol. iv. p. 157; Quarterly Journal iv. 274, and vii. 100; and Ann. Phil. N. S. xii. 81, 296.

§ If gold is suspected in the solution, it may be detected by dropping in a solution of muriate of tin; when present, a purple precipitate will appear.

¶ For analysis of phosphate of iron, see Ann. de Chim. et de Phys. xxx. 202; for that of arseniate of iron, see Phil. Trans. 1801, p. 219.

acid. The oxide, of tin was analyzed by Klaproth, as follows: One hundred parts of the ore were heated to redness, with six hundred parts of potassa in a silver crucible, and the mixture being treated with warm water, eleven parts remained undissolved. These eleven, by a repetition of the treatment with potassa, were reduced to one part and a quarter. This small residuum was dissolved in muriatic acid. Zinc precipitated from the solution, one half part of tin; and the Prussian alkali gave a blue precipitate, which indicated one fourth part of iron. The alkaline solution was saturated with muriatic acid; a white precipitate appeared, but it was redissolved by adding more acid. The whole was precipitated by carbonate of soda. The precipitate, which had a yellowish color, was redissolved in muriatic acid; and a cylinder of zinc, being inserted into the solution, seventy seven of tin were obtained, indicating nearly ninety eight parts of the oxide of tin.

(f.) *Ores of Lead* may be analyzed by solution in diluted nitric acid. The sulphur, if any, will remain undissolved. The solution is precipitated by carbonate of soda. If silver is present, it is taken up by pure ammonia. The precipitate is washed, and to it, is added, concentrated sulphuric acid,—applying heat, so that the nitric acid may be wholly expelled. The sulphate of lead is calcined, and weighed; every 100 parts = 68 lead.

(g.) *Ores of Mercury*.—Mercury may be detected in ores that contain it, by distilling them in an earthen retort, with half their weight of iron filings, or dry lime; the mercury will rise, and be condensed in the receiver.

(h.) *Ores of Zinc* may be digested with nitric acid, and the part that is dissolved be boiled to dryness; again dissolved in the acid, and again evaporated to dryness. By these means, the iron, if any be present, will be rendered insoluble in dilute nitric acid, which will take up the oxide of zinc. To this solution, liquid ammonia is added, in excess, which separates the lead and iron, if any has been dissolved; the excess of alkali retaining the oxide of zinc. This is precipitated by the addition of an acid, or by the evaporation of the solvent. To separate zinc from iron and manganese, the compound may be dissolved in muriatic acid; the iron thrown down by benzoate of ammonia, and the manganese by the chloride of lime. The precipitate is red, and after ignition, six parts of it is equivalent to five of deutoxide of manganese. The zinc is finally precipitated by means of hydrosulphuret of ammonia.

(i.) *Ores of Antimony*.—Sulphuret of antimony is dissolved in three or four parts of muriatic, and one of nitric acid, which takes up the antimony and leaves the sulphur. On dilution with water, the oxide of antimony is precipitated, and the iron and mercury remain dissolved. If lead is present, it is precipitated by sulphuric acid. The iron is thrown down by ammonia.

(k.) *Ores of Arsenic* may be digested with nitro-muriatic acid; the solution evaporated to one fourth, and water added which precipitates the arsenic. The iron is afterwards separated by ammonia; or the arsenic and sulphur may be acidified, and the iron separated in the state of a peroxide; the arsenic and sulphuric acids, both thrown down by baryta, and the arseniate of baryta separated from the sulphate, by means of nitric acid.

(l.) *Ores of Bismuth* are digested in nitric acid, moderately diluted. The addition of water, precipitates the oxide, as a sub-nitrate; but if not wholly separated at first, the solution is evaporated, after which, a further addition of water separates the remainder.

(m.) *Ores of Cobalt*.—Cobalt is detected, if the solution of an ore in muriatic acid, give a sympathetic ink. To analyze an ore of this metal, we dissolve it in nitro-muriatic acid, and then add carbonate of potassa, which, at first, separates iron and arsenic. The solution is filtered, and a farther quantity of the carbonate is added; when a grayish red precipitate will fall, which is oxide of cobalt. The iron and arsenic are separated by heat, which volatilizes the arsenic.

(n.) *Ores of Nickel* are dissolved in nitric acid, and to the solution is added ammonia in large excess, which precipitates most other metals, while it retains the oxide of nickel in solution. The nickel is obtained by evaporating the supernatant liquid to dryness, and heating the dry mass till the nitrate of ammonia is sublimed.

(o.) *Ores of manganese*.—The earths, and several of the metals contained in these ores, may first be separated by diluted nitric acid, which does not act on highly oxidized manganese. The ore may afterwards be digested with strong muriatic acid, which will take up the oxide of manganese. Chlorine gas will arise, if a gentle heat be applied, and may be known by its peculiar smell. From muri-

atic acid the manganese is precipitated by carbonate of soda, in the form of a white carbonate, which becomes black per-oxide, when heated in a crucible. When iron is present, it may be separated according to the rules given under analysis of earths.*

ANALYSIS OF INFLAMMABLE MINERALS.

It is seldom necessary to perform exact analyses of the minerals included within the present class; a few general rules, therefore, for determining the quality of the different kinds of coal, and of sulphur, is all that is requisite to add, in order to complete the present subject.

(a.) *Sulphur*.—Sulphur should be entirely volatilized by distillation in a glass retort. If any thing remain fixed, it must be considered as an impurity, and may be examined by the rules given under the preceding divisions. Sulphur, also, should be wholly dissolved, by boiling with solution of pure potassa, and may, in this manner, be separated from its impurities. Oxide of iron, silica, and many other impurities, are conveniently detected in sulphur, by projecting it into a red-hot crucible: the sulphur burns off, and leaves the contaminating substances behind.

(b.) *Coals*.—The proportion of bituminous matter in coal, may be learned, by distilling a known quantity, at a heat below redness, in an earthen retort, and collecting the condensable fluids. The earthy, or metallic impurities, are determined, by burning the coal, with access of air, on a red-hot iron; they remain behind, and may be examined by the rules, laid down in the foregoing pages. The proportion of carbon may be ascertained, by observing the quantity of nitrate of potassa, which a given weight of the coal is capable of decomposing. For this purpose, 500 grains or more, of perfectly pure nitre, are melted in a crucible, and, when red-hot, the coal to be examined, reduced to a coarse powder, is projected on the nitre, by small portions at once, not exceeding one or two grains. The proportion of carbon in the coal, is directly proportionate to the quantity, required to alkalyze the nitre. Thus, since 12.709 of carbon, are required to alkalyze 100 of nitre, it will be easy to deduce the quantity of carbon, in a given weight of coal, from the quantity of coal which it is capable of decomposing.†

* For analysis of the following ores, the reader is referred to the works noted in connexion with their names.

Ores of Uranium.—Ann. of Phil. v, 281.—do. N. S. 111, 99; and v, 57.

Ores of Tungsten.—Klaproth's Analytical Essays; D'Elhuyart, *Memoires de l'acad. de Toulouse*, 11; Vauquelin, *Journ. des Mines*, No. xix; and Ann. de Ch. et de Ph. xxx, 184.

Ores of Molybdenum.—Phil. Trans. 1796; and Klaproth, Vol. 1, p. 534, 538.

Ores of Titanium.—Journ. de Physique, xxxix, 72, 152; Klaproth, 1, 496; and Nicholson's Journal, v, 132.

Rose separates titanate acid from iron, in the following manner:—A solution of titanate acid and iron, being obtained in muriatic acid, if tartaric acid be added to it, and the whole be diluted with water, then, a great excess of caustic ammonia may be added, without the smallest precipitate of titanate acid, or oxide of iron, being produced. If to this solution, hydro-sulphuret of ammonia be added, it exerts no action on the titanate acid, but changes all the oxide of iron into sulphuret, which separates perfectly. This precipitate is to be carefully washed with water, containing a few drops of hydro-sulphuret of ammonia, until all the tartrate is removed: it is then to be dissolved in muriatic acid, heated, to drive off the sulphuretted hydrogen, treated with nitric acid, to per-oxidize the iron, and then precipitated by ammonia. In this way, the iron is procured. The titanate acid may be separated from the solution (if it contains no fixed parts) by evaporating to dryness, and heating red hot, in contact with air, until all that is volatile is dissipated, and the charcoal is burnt off. This is best done in a small platina crucible, in a muffle; titanate acid remains.

Ores of Tellurium.—Klaproth, 11, 1.

Ores of Chromium.—Ann. de Chim. xxv.

Ores of Columbium.—Phil. Trans. 1802; Ann. de Chim. xliii, 276.

Ores of Palladium and Rhodium.—Phil. Trans. 1805, 1809 and 1829; Quart. Jour. xii; and Berzelius in Ann. de Ch. et de Ph. xl.

Ores of Iridium and Osmium.—Phil. Trans. 1804; Quart. Jour. xii, 247; and Berzelius in Ann. de Ch. et de Ph. xl.

Ores of Cerium.—Nicholson's Jour. 8vo. xii.

† A more accurate method of analyzing the different varieties of coal, is by ignition with per-oxide of copper. (See Ann. Ph. Vol. xvi.)

CORRECTION OF ANALYSIS, BY MEANS OF THE ATOMIC THEORY.

It may now be considered as fully established, that the constituents of simple minerals are in true atomic proportions. Hence, the chemist is at once furnished with an easy, and almost infallible test of the accuracy of his analyses of these compounds, in the coincidence of their results, with the atomic weights of the several constituents. The method of calculating the results of a mineral analysis, on the atomic theory, is best illustrated by a few examples.

1. Taking the analysis of the Deweylite,* in which we have found,

Silica,	. . .	40
Magnesia,	. . .	40
Water,	. . .	20

100

Here, a certain number of atoms of silica, lime, and water, whose weights respectively are 40, 40, and 20, are combined together. If we divide the weight of each ingredient by the number representing its atomic weight, we shall find its relative number of atoms in the compound. The atom of silica (as a reference to the table of atomic weights will show) = 16, that of magnesia = 20, and that of water = 9.

$$\begin{array}{rcl}
 \frac{4000}{16} & = & 250 = 5 \text{ of silica.} \\
 \frac{4000}{20} & = & 200 = 4 \text{ of magnesia.} \\
 \frac{2000}{9} & = & 222 = 4 \text{ of water.}
 \end{array}$$

To obtain the sum of all the atoms,

$$\begin{array}{rcl}
 5 \times 16 & = & 80 \\
 4 \times 20 & = & 80 \\
 4 \times 9 & = & 36
 \end{array}$$

196.

To find its theoretical composition, therefore, we have only to employ the rule of simple proportion; thus,

as $196 : 80 :: 100 : x$, and $x = 40.81$; and so with the other atoms.

The composition of the mineral, as inferred from analysis, and from theory, will stand as follows.

	<i>Experiment.</i>	<i>Theory.</i>
Silica,	40.00	40.81
Magnesia,	40.00	40.81
Water,	20.00	18.36
	100.00	99.98.

From which it is seen, that the results of experiment accord very nearly with those derived from the doctrine of definite proportions.

2. Taking an analysis of zoisite, in which were found,

Silica,	. . .	43.00
Alumina,	. . .	33.00
Lime,	. . .	24.00

100.00.

The atom of alumina = 18, and that of lime = 28.

$$\begin{array}{rcl}
 \frac{4300}{18} & = & 238 = 3 \text{ of silica.} \\
 \frac{3300}{18} & = & 183 = 2 \text{ of alumina.} \\
 \frac{2400}{28} & = & 85 = 1 \text{ of lime.}
 \end{array}$$

* American Journal of Science and Arts, Vol. xviii, p. 82.

The sum of the atoms, therefore, = 110; and the composition of zolite, by experiment and calculation, stands thus:

	<i>Experiment.</i>	<i>Theory.</i>
Silica, .	43.00	43.63
Alumina, .	33.00	30.90
Lime, .	24.00	25.45
	<hr/> 100.00.	<hr/> 99.98.

3. Let us take Mr. Hatchett's analysis of iron pyrites, in which he found,

Iron,	47.85
Sulphur,	52.15
	<hr/> 100.00.

The atom of iron = 28; that of sulphur = 16.

$$\begin{array}{r} 47.85 \\ 28 \\ \hline 1.67 \\ \times 170 \\ \hline 52.15 \end{array} = 170 = 1 \text{ of iron.}$$

$$\begin{array}{r} 52.15 \\ 16 \\ \hline 3.26 \\ \times 32 \\ \hline 105.00 \end{array} = 325 = 2 \text{ of sulphur.}$$

The sum of the atoms, therefore, = 60; and the composition, by experiment and theory stands thus:

	<i>Experiment.</i>	<i>Theory.</i>
Iron,	47.85	46.66
Sulphur,	52.15	53.33
	<hr/> 100.00.	<hr/> 99.99.

The mode in which the elements of a mineral are combined, is an after consideration; and must be regarded as only conjectural: though, in a great multitude of cases, we are left to entertain no reasonable doubt of the nature of this combination. Thus, in the instance of sulphuret of iron, just given, we may be confident that the compound is a bi-sulphuret of iron, consisting of 2 atoms of sulphur, and 1 atom of iron; for, by the table of equivalents, we find that 60 is the atomic weight of the bi-sulphuret of iron; and we discover that 32 (the sulphur in the bi-sulphuret of iron) : 28 (the iron in the same) :: 53.33 (the sulphur in the pyrites) : 46.66 (the iron in the same.)

II. ANALYSIS OF MINERAL WATERS.

Those waters which contain so much foreign matter as to have a sensible taste, and a decided action on the animal economy are called mineral waters. Their temperature varies from that of the atmosphere to nearly 212° F.; and according as it is higher or lower, they have received the denomination of thermal, or cold, springs. The substances they contain are very numerous. Among the most common, are, carbonic acid; sulphuretted hydrogen; carbonates, sulphates, and muriates of soda, lime and magnesia; and carbonate and sulphate of iron. Those of more rare occurrence, are oxygen and nitrogen gases, sulphate of alumina, muriate of manganese, silica, boracic, hydriodic, hydro-bromic and fluoric acids, lithia, strontia, soda and potassa. From the predominance of a few of these ingredients, mineral waters are often characterized; thus, those which abound in carbonic acid, are termed *carbonated* waters,—those which contain sulphuretted hydrogen, *sulphureous* waters,—those in which iron is a predominate ingredient, *chalybeate* waters,—and finally those in which several neutral salts are dissolved, *saline* waters.

PRELIMINARIES IN THE EXAMINATION OF MINERAL WATERS.

The topography of the place where the water to be examined occurs, is the first thing that requires attention. Particular regard should be paid to the nature of the strata or soils through which they ooze, since from this source a tolerably correct opinion may often be formed of their contents. The sensible properties of waters next deserve attention. The temperature, as determined by the thermometer, is to be ascertained. The appearance of the water immediately on being raised from the spring, as well as after it has been suffered to stand for some time, affords several indications from which important inferences may be deduced. If the water be turbid at first, the substances are suspended only, and not dissolved; but if the water be clear and transparent at the well, and some time intervenes before it becomes

turbid, the contents are dissolved by means of carbonic acid; the presence of which, is also indicated by small bubbles that rise from the bottom of the well, and burst in the air, on arriving at the surface. But the most evident proof of a spring containing carbonic acid, is the generation of bubbles on the water being shaken, and their bursting with more or less noise, while the air is making its escape. The sediment deposited by the water is likewise to be examined. If it be yellow, it indicates the presence of iron; if black, that of iron combined with sulphur. The odor of water is important in discovering the presence of sulphuretted hydrogen in them; such as contain this substance have the peculiar fetid smell belonging to this gas. The taste of a spring affords useful indications with respect to its contents. Specific gravity is less important in judging of the contents of mineral waters, though it should not always be overlooked.

The examination of waters, by the application of a few reagents, enables us to discover the substances they contain; but to determine the proportions and manner in which they are combined, requires a complete analysis. The former, of these objects, is often all that is sought, in relation to the mineral waters; and when the latter is aimed at, it can be effected only, by first ascertaining all the ingredients that are present. In making these preliminary experiments, the water employed, should, in general, be taken fresh from the spring, or should have been preserved from the air in sealed bottles. Occasionally, however, it needs to undergo an exposure to the air, for the space of a few hours; and when the saline ingredients are not abundant, it sometimes requires to be considerably evaporated. The substances detected by testing, are:

(a.) *Carbonic acid*.—When this is not combined with any base, or not with sufficient to neutralize it, the addition of lime or barytic water, in excess, will throw down a precipitate, soluble with effervescence in muriatic acid. It reddens litmus faintly, when fresh, but loses this property after boiling, or long exposure to the air; and, if litmus has been reddened by it, the color is discharged by boiling.

(b.) *Mineral acids*, when present, uncombined, in water, reddens litmus permanently, even though the water has been boiled.

(c.) *Sulphuretted hydrogen* exhales its peculiar odor, blackens paper moistened by solution of lead or bismuth, and precipitates the nitrate of silver black or brown; but it loses these properties by being boiled.

(d.) *Hydro-sulphuret*, with excess of gas, is attended with the same smell as sulphuretted hydrogen, but weaker; it also precipitates solutions of lead and silver black; but heat does not destroy either of these properties.

(e.) *Alkalies and alkaline, and earthy carbonates* are distinguished by the following tests.—The infusion of turmeric, or paper stained with turmeric, is rendered brown by alkalies, or reddish brown, if the quantity be minute. Paper stained with the infusion of Brazil wood, is rendered blue; but this change is produced also by the alkaline and earthy carbonates. Litmus paper, reddened by vinegar, is restored to its original blue color; a change is produced by the alkaline and earthy carbonates also. When these changes are fugacious, we may conclude that the alkali is ammonia. Fixed alkalies exist in waters that occasion a precipitate with muriate of magnesia after being boiled. The volatile alkali may be distinguished by the smell, or by white fumes with muriatic acid; or it may be obtained in a receiver, by distilling a portion of the water gently, and then it may be distinguished by the above tests. Earthy (as well as metallic) carbonates are precipitated by boiling the water containing them; except the carbonate of magnesia, which is precipitated but imperfectly.

(f.) *Iron*.—Tincture of galls imparts, to water containing iron, a purple or black color. If the tincture have no effect on water after boiling, though it colors it before, the iron is in the state of a carbonate. When the iron is a little oxidized, the presence of lime, facilitates the application of this test; but when on the contrary, the iron is much oxidized, lime prevents the ordinary action of the test. Ferro-cyanate of potassa occasions a blue precipitate in water containing iron. If an alkali be present, however, the blue precipitate does not appear, unless the alkali is first saturated with an acid.

(g.) *Copper*.—Ammonia gives to water, containing any of the salts of copper, a blue tinge; and if the solution is strong, a plate of clean iron, immersed in them, comes out covered with a thin coat of copper.

(h.) *Sulphuric acid* exists in waters that form a precipitate, with the following solutions:—muriate, nitrate, or acetate of baryta, strontia, or lime, or nitrate or ace-

tate of lead. Of these, the most powerful by far, is muriate of baryta, which should be applied with the following precautions: the muriate must be diluted; the alkalies, or alkaline carbonates, if the water contain any, must be previously saturated with muriatic acid; the precipitate must be insoluble in muriatic acid; if boracic acid be suspected, muriate of strontia must be tried, which is not precipitated by boracic acid. The hyro-sulphurets precipitate barytic solutions, but their presence is easily discovered by the smell.

(i.) *Muriatic acid* is detected by nitrate of silver, which occasions a cloud or a white precipitate. To render this test certain, the alkalies, or carbonates, must be first saturated with nitric acid; and sulphuric acid, if present, must be previously removed by means of nitrate of baryta. The precipitate must be insoluble in nitric acid.

(j.) *Hydriodic acid* is detected, by adding to the water, rendered dense by evaporation, in the first place, a solution of starch, and then a few drops of sulphuric acid; the starch assumes a deep blue color. Solution of muriate of platinum causes a deep brownish red color, and, in a few hours, the liquid is covered by a metallic film.*

(k.) *Hydro-bromic acid* is detected in mineral waters, by passing a current of chlorine gas through the water, first rendered dense by evaporation: it assumes a deep orange yellow color, and by adding to it pure sulphuric ether, and agitating the fluids together, the yellow color disappears from the aqueous solution, and rises in the ether to the top of the fluid, which it colors of a rich, reddish brown color.

(l.) *Nitric acid* is detected, by adding sulphuric acid to a portion of the water in which it exists, in quantity abundantly sufficient to decompose all the salts subject to its action, and boiling such acidulated water in a Florence flask, with a leaf of gold, for half an hour, or an hour: the gold will, either in part, or wholly, disappear; and the solution obtained, will give, on the addition of proto-muriate of tin, a deep purple tint; also, by adding to a portion of the water a solution of potassa, till no further precipitate falls down, and then filtering and evaporating the supernatant liquid; a residuum will be obtained, which scintillates when thrown on burning coals.

(m.) *Boracic acid* is detected, by means of acetate of lead, with which it forms a precipitate, insoluble in acetic acid. But, to render this test certain, the alkalies and earths must be previously saturated with acetic acid, and the sulphuric and muriatic acids removed, by means of acetate of strontia and acetate of silver.

(n.) *Baryta* is known by the insoluble white precipitate, which it forms with diluted sulphuric acid.

(o.) *Lime* is detected by means of oxalic acid, which occasions a precipitate in water, containing a very minute proportion of this earth. To render the test decisive, however, the mineral acids, if any be present, must be previously saturated with an alkali; and baryta, if any be present, must be removed by means of sulphuric acid. Oxalic acid precipitates magnesia, but very slowly, whereas it precipitates lime instantly.

(p.) *Lithia* is detected in mineral waters, in the following manner:—into the mineral water, pour a solution of phosphate of soda, evaporate to dryness, and redissolve all that is soluble by cold water. Lithia, if present, is left in the state of an insoluble phosphate of lithia and soda.

(q.) *Magnesia and alumina*.—The presence of these earths is ascertained by the following tests:—ammonia precipitates them both, provided the carbonic acid has been previously separated by a fixed alkali, and boiling. Lime water precipitates only these two earths, provided the carbonic acid be previously removed, and the sulphuric acid also, by means of nitrate of baryta. The alumina may be separated from the magnesia, after both have been precipitated together, either by boiling the precipitate in potassa, which dissolves the alumina, and leaves the magnesia; or the

* M. Ballard's mode of testing for iodine.—After having mixed the liquid containing the iodine, with the starch and the sulphuric acid, a small quantity of aqueous solution of chlorine is to be added, which, from its lightness, may be made not to mix with the mixture, but float on the surface; at the place, where they touch, a blue zone will be perceived, which, however feeble it may be, is readily seen by contrast with the neighboring limpid liquids; if a part of the mixture be slightly agitated, the blue color will be developed when the two solutions are in contact; but if the whole be mixed, it will entirely disappear, if the chlorine be in excess.

precipitate may be dissolved in muriatic acid, precipitated by an alkaline carbonate, dried in the temperature of 100° , and then exposed to the action of diluted muriatic acid, which dissolves the magnesia, without touching the alumina.

(*r.*) *Silica*, may be ascertained, by evaporating a portion of water to dryness, and redissolving the precipitate in muriatic acid: the silica will remain behind untouched.

By these means, the substances found in mineral waters, may be detected; but as they are generally combined, so as to form salts, it remains to point out the methods for discovering what these combinations are.

1. *Sulphates*.—When we have detected sulphuric acid, combined, and one base or more, in a water, the next step is to ascertain the species of the sulphate. The number of sulphates, hitherto observed in water, is seven; but as one of these, sulphate of copper, is never found, except in the vicinity of copper mines, it may be left out of the question, in our ordinary researches.

Sulphate of soda, or sulphate of potassa, may be detected by the following method:—To free the water of all earthy sulphates, it is evaporated to one half, and lime water added as long as any precipitate appears. The only remaining earthy sulphate will be sulphate of lime, which is separated by evaporating the liquid till it becomes concentrated, and then dropping into it a little alcohol, and after filtration, adding oxalic acid in small quantities. With the water, thus purified, is mingled a solution of lime. If a precipitate appear, either immediately, or on the addition of a little alcohol, it is a proof that sulphate of potassa, or of soda, is present. Which of the two, may be determined by mixing some of the purified water considerably reduced in bulk, by evaporation, with a solution of muriate of platinum. If the alkali be potassa, a yellow precipitate will fall; but none will appear if the alkali be soda.

Sulphate of lime may be detected by evaporating a quart of the water, suspected to contain it, to a few ounces. A precipitate appears, which if it be sulphate of lime, is soluble in 500 parts of water; and the solution affords a precipitate with the muriate of baryta, oxalic acid, carbonate of magnesia and alcohol.

Alum may be detected by mixing carbonate of lime with the water in which it exists; if a precipitate appear, it indicates the presence of alum, or at least of sulphate of alumina; provided the water contains no muriate of baryta or metallic sulphates. The first is incompatible with alum, the second may be removed by the alkaline prussiates. When a precipitate is produced in water by muriate of lime, carbonate of lime, and muriate of magnesia, we may conclude that it contains alum or sulphate of alumina.

Sulphate of magnesia may be known by the following tests;—a solution of carbonate of ammonia (prepared with a portion of that salt which has been exposed) is added to the water, much reduced by evaporation; after which phosphate of soda is added, which will throw down a precipitate of the ammoniaco-magnesian phosphate. A neat mode of applying this test was practiced by Dr. Wollaston, its inventor, as follows:—upon a piece of glass, the clear solution containing magnesia is spread so as to form a thin film, to which are added a few drops of carbonate of ammonia, and phosphate of soda in succession: the word magnesia, or any other, is then traced upon the glass so covered, with the end of a glass rod. The word which is traced will appear in white characters. Objections have been made to these tests however, by Mr. R. Phillips, on the ground of the presence of carbonate of lime in all sesquicarbonate of ammonia, which may cause in the addition of phosphate of soda, a precipitate of phosphate of lime as well as one of the ammoniaco-magnesian phosphate. Hence the original test, made use of by Kirwan, is perhaps to be preferred. Hydro-sulphuret of strontia added to a water containing sulphate of magnesia occasions an immediate precipitate with this salt and with no other, provided the water be previously deprived of alum, if any be present, by means of carbonate of lime, and provided, also, that it contain no uncombined acid.

Sulphate of iron is inferred, if a solution of nut-galls or of ferro-cyanate of potassa, continue to produce their usual ferruginous reaction after the water has been boiled and filtered.

2. *Muriates*.—The most common by far is muriate of soda, which, when it is not accompanied by a great variety of substances, may be very conveniently detected by crystallization. For this purpose a portion of the water is evaporated by a very gentle heat, not exceeding 80° or 90° . As soon as a pellicle appears in the solution, it may be removed, and cautiously dried on bibulous paper, and exam-

ined with a magnifier: the cubical form of the crystal belonging to this salt will generally be discoverable. When numerous salts, however, are contained in the same solution, it may sometimes be difficult to detect its presence in this way. In such cases, the combined muriatic acid must be sought for by a solution of nitrate of silver, taking care to add in the first place a few drops of nitrate of baryta, and allowing the precipitate to subside:* if now, on the addition of the solution of silver a precipitate take place, a muriate may be inferred with certainty,—but whether it be of soda, potassa, lime, or magnesia, or of several of these, is not certain.

Separate tests must be applied for these; and the alkalies, when present, may be distinguished from each other, by the peculiar salts which they form with the different acids. With tartaric acid, soda forms a soluble salt; while with potassa, an acidulous tartrate is formed, of comparatively sparing solubility. Muriate of platinum affords a still more delicate test, as has been noticed above.

Muriate of baryta may be detected by sulphuric acid, as it is the only barytic salt hitherto found in water.

Muriate of lime may be detected by the following method:—Free the water from sulphate of lime, and other sulphates, by evaporating it from a considerable bulk to a few ounces, mixing it with alcohol, and adding last of all nitrate of baryta, as long as any precipitate occurs. Filter the water; evaporate to dryness; treat the dry mass with alcohol; evaporate the alcohol to dryness, and dissolve the residuum in water. If this solution give a precipitate with acetate of silver and oxalic acid, it may contain muriate of lime. It must in that case, contain it if after being treated with carbonate of lime, it give no precipitate with ammonia. If the liquid in the receiver give a precipitate with nitrate of silver, muriate of lime existed in the water.

Muriate of magnesia may be detected by separating all the sulphuric acid, by nitrate of baryta. The clear fluid, separated from the precipitate, is evaporated to dryness, and the residuum treated with alcohol. The alcoholic solution is then evaporated in turn, and the dry residue dissolved in water. The muriate of magnesia, if the water contained any, will be found in this solution. Let us suppose, that by the tests formerly mentioned, the presence of muriatic acid, and of magnesia, in this solution, has been ascertained. In that case, if carbonate of lime afford no precipitate, and if sulphuric acid and evaporation, together with the addition of a little alcohol, occasion no precipitate, the solution contains only muriate of magnesia. If these tests give precipitates, we must separate the lime which is present, by sulphuric acid and alcohol, and distil off the acid with which it was combined. Then the magnesia is to be separated by the oxalic acid and alcohol, and the acid with which it was united is to be distilled off. If the liquid in the retort give a precipitate with nitrate of silver, the water contains muriate of magnesia.

8. *Nitrates*.—These seldom occur in waters. When they do, they may be detected in the following manner:—Alkaline nitrates may be discovered by having the water examined for sulphuric acid by means of acetate of baryta, and for muriatic acid by acetate of silver. The filtered liquor is evaporated to dryness, and the dry mass treated with alcohol. What the alcohol leaves undissolved, must consist only of the alkaline nitrates, and acetate of lime. It is dissolved in water; and carbonate of magnesia added, which will occasion a precipitate if lime be present. The lime is separated by farther additions of carbonate of magnesia. The liquid is filtered, evaporated to dryness, and the residuum treated with alcohol. The alcohol now leaves only the alkaline nitrates, which may easily be recognized by their respective properties. Nitrate of lime is detected by concentrating the water, and mixing it with alcohol to separate the sulphates. The liquid is filtered and the alcohol distilled off; the muriatic acid is then separated by the addition of acetate of silver. The solution is filtered, evaporated to dryness, and the residuum dissolved in alcohol. The alcoholic solution is evaporated to dryness, and the dry mass dissolved in water. If this last solution indicates the presence of lime by the usual tests, the water contained nitrate of lime.

To detect nitrate of magnesia, the water is to be freed from sulphates and nitrates, as above. The liquid thus purified, is to be evaporated to dryness, and the re-

* The nitrate of silver being decomposed by the sulphuric acid.

sodium treated with alcohol. The alcoholic solution is also to be evaporated to dryness, and the dry mass dissolved in water. To this solution potassa is to be added, as long as any precipitate appears, and the solution filtered, and again evaporated to dryness, is to be treated with alcohol. If it leave a residuum consisting of nitre, the water contained nitrate of magnesia.

Such are the methods usually practiced for discovering the different saline contents of mineral waters. Only a small number of these will be necessary to ascertain the nature of any particular water; for having proved the existence of certain salts in a water, we may be confident, from the known incompatibility of some salts with each other, that certain others cannot be present with them, and thus we are enabled to forego the trouble of examining for them. The following table will show the experimenter those salts which are incapable of existing together in a water, except in very minute proportions;

<i>Salts.</i>	<i>Incompatible with</i>
Fixed alkaline sulphates,	{ Nitrates of lime and magnesia, Murates of lime and magnesia.
Sulphate of lime, - -	{ Alkalies, Carbonate of magnesia, Muriate of baryta.
Alum, - - - - -	{ Alkalies, Muriate of baryta, Nitrate, muriate, carbonate of lime, Carbonate of magnesia.
Sulphate of magnesia,	{ Alkalies, Muriate of baryta, Nitrate and muriate of lime.
Sulphate of iron, - -	{ Alkalies, Muriate of baryta, Earthy carbonates.
Muriate of baryta,	{ Sulphates, Alkaline carbonates, Earthy carbonates.
Muriate of magnesia,	{ Alkaline carbonates, Alkaline sulphates.
Nitrate of lime,	{ Alkaline carbonates, Carbonates of magnesia and alumina, Sulphates, except lime.

TO DETERMINE THE PROPORTIONS OF THE INGREDIENTS IN MINERAL WATERS.

It is not sufficient to know, that a mineral water contains certain ingredients; it is necessary to ascertain the proportions; and thus we arrive at their complete analysis. The following method of procedure is of general application:—To collect, in the first place, the gases; and in the second, the solid matter contained in the water: the latter is then divided into three portions;—the first containing all the substances very soluble in water; the second those that are soluble in alcohol, and the third those that are insoluble in both.

To collect the Gases.

For azote and oxygen, a bent tube is adapted to a flask, filled with the water, and the end of the tube passes under a jar filled with mercury over the mercurial trough: the water is boiled till all the gas is evolved. A little potassa, or soda, is passed up into the jar to absorb any carbonic acid or sulphuretted hydrogen which the water may contain; but the alkali is not introduced till after the gas is collected, and if the water is sulphureous, as when it contains the hydrosulphuret of potassa or soda, it is liable to absorb a portion of the oxygen gas when left long in contact with it. Having thus obtained the whole of these gases from a given quantity of the water, their respective quantities is determined by the ordinary method of causing the oxygen to be absorbed, by hydrogen or phosphorus, and leaving the azote free. Mineral waters, however, usually contain less of these gases than common water, and they are therefore very seldom objects of research.

To ascertain the quantity of carbonic acid, a pint flask with a bent tube is filled with the water;—the bent tube passing to the bottom of a graduated jar filled with mercury over the mercurial cistern. The flask may be placed up to its neck in a tin kettle filled with a saturated solution of common salt, which must be kept boiling for an hour or two,—renewing by fresh portions of hot water what is lost by evaporation. On the first impression of the heat, however, the water in the flask will itself be expanded, and portions will continue to escape into the graduated jar, till the water has attained its maximum of temperature. This portion must be measured, and its quantity deducted from that of the water submitted to experiment. When the gas is wholly expelled, a solution of potassa is introduced into the receiver; and the absorption indicates the quantity of carbonic acid present in the water.* If the water contains sulphuretted hydrogen along with carbonic acid, the process must be varied, since both of these gases are absorbed by potassa. A vessel holding a larger portion of the water (say five hundred cubic inches,) must be employed, and the bent tube must dip under a jar containing a mixture of ammonia and muriate of lime. The carbonic acid will first unite with the ammonia, and the carbonate thus formed will then decompose the muriate of lime, and a precipitate of carbonate of lime will fall. This must be carefully collected and dried and from its weight, that of the carbonic acid, and consequently its volume is obtained: 100 parts of carbonate of lime indicate 48.7 parts of carbonic acid, and 100 cubic inches of the gas weighs at the mean temperature and pressure 46.57 grs. If the water contain sulphurous acid, a little acetate of lime is added before it is heated; otherwise it would be partially volatilized, and a portion of insoluble sulphite of lime be mixed with the carbonate. The quantity of sulphuretted hydrogen may be ascertained by a similar process, substituting acetate of lead for the ammonia and muriate of lime; sulphuret of lead is formed and precipitated in black flakes, while the carbonic acid remains free. 100 parts sulphuret of lead contain 86.6 of lead, and 13.4 of sulphur; and 100 cubic inches of sulphuretted hydrogen gas at mean pressure and temperature, weigh 36 grs. It is easy therefore from the weight of the sulphuret, to find the quantity of gas.

Sulphurous acid is very rarely found in mineral waters; but if met with, it must be converted by chlorine into sulphuric acid, precipitated by nitrate of baryta, and the sulphate collected, washed, dried and calcined;—100 parts of this salt represent 27.5 of sulphurous acid by weight. If a water also contains sulphuric acid, or a sulphate, a second portion, to which no chlorine has been added, must likewise be treated with nitrate of baryta; and the weight of this precipitate deducted from the former; 100 parts of sulphate of baryta contain very nearly 34 of sulphuric acid.

Sub-carbonate of ammonia is as seldom found in mineral waters, as sulphurous acid. Its quantity may be ascertained, by distilling a portion of the water, condensing the vapor in a receiver, containing a little muriatic acid, and evaporating the liquid to dryness. The quantity of muriate of ammonia obtained, will give that of the carbonate: 100 parts of the former, indicating 73.5 of the latter.

Separation of the solid ingredients.

A sufficient, measured quantity of the water, is evaporated in a tinned copper, or silver basin, till it is reduced to about a pint; when it is transferred to a porcelain basin, (taking care to scrape off any solid matter that may adhere to the sides of the copper vessel, and to rinse it with water) and the evaporation is continued to dryness. Having thus obtained two or three hundred grains of the residuum, we proceed as follows:

A certain quantity, (100 grs. for instance) previously well dried, at a temperature not exceeding 212°, is boiled with seven or eight times its weight of water, for the space of a few minutes: if the liquid is turbid, it is filtered, and the insoluble matter separated by the filter, is dried and weighed.

The aqueous solution is evaporated to dryness; the residuum is weighed, and digested in successive portions of alcohol, (of the sp. gr. .825) with a gentle heat: the liquor is filtered, and the filter washed repeatedly with alcohol. The alcoholic solution is evaporated to dryness, and the residuum dried and weighed.

* In determining with precision the quantity of gases in mineral waters, it is necessary to attend to the state of atmospheric pressure, temperature, &c. The rules for reducing observations made under different states of the barometer and thermometer to a mean standard, have been given in the first Vol. of this work. p. 179.

The fixed ingredients will thus be separated into three portions : their nature and mode of farther separation from each other, remain to be considered.

The insoluble portion may contain the carbonates of lime, magnesia and iron-sulphate of lime, and silica. The carbonates are dissolved in a very slight excess of muriatic acid; and the undissolved portion separated by the filter. A considerable excess of muriatic acid is now added to the clear liquid; and the oxide of iron is precipitated by ammonia, the weight of which, when dried and ignited, is that of the carbonate of iron. The lime and magnesia, which remain in the solution, may be separated according to the rules before given. The sulphate of lime, and silica, which were left behind when the muriatic acid was added, may be separated by sub-carbonate of potassa and muriatic acid. The alkali will decompose the sulphate of lime, and the acid dissolves the carbonate which is formed, whilst the silica will remain untouched. The sulphate of lime may then be re-produced, by again separating the earth by sub-carbonate of potassa, or soda, and combining the precipitate with sulphuric acid.

The muriates and nitrates of lime and magnesia, soda, hydro-sulphuret of soda, muriate of ammonia, and common salt, are the only substances soluble in alcohol, likely to be present in a mineral water; and of the two latter, alcohol dissolves but a very small quantity. Soda, which, as well as muriate of ammonia, is of very rare occurrence in mineral waters, is incompatible with magnesian and calcareous salts, and with muriate of ammonia; so that it can be found only in the alcoholic solution, associated with the muriate or hydro-sulphuret of soda: consequently, when a mineral water contains no sulphuretted hydrogen, which is always easily known, and is most frequently the case, the portion soluble in alcohol, will probably consist only of the muriates and nitrates of lime and magnesia, and muriate of soda. Dissolve the salts in water, and to the solution add cautiously, drop by drop, acetate of silver, until no further precipitate ensues; avoiding, as much as possible, any excess of the precipitant. The whole of the muriatic acid will thus be separated, and there will remain in solution, the acetates of lime, magnesia, and soda, and the nitrates of lime and magnesia. Evaporate to dryness, by a gentle heat, taking care not to decompose the acetates by too high a temperature. Digest the dry mass in rather less than twice its weight of cold alcohol, of the sp. gr. .850. This will dissolve the acetates and nitrates of lime and magnesia, and leave the acetate of soda. Decant the alcoholic solutions, wash the residuum with fresh alcohol, and add the washings to the decanted portion. The acetate of soda may then be converted into sub-carbonate by a red heat, and weighed. Distil off the alcohol from the dissolved salts, re-dissolve them in water, and to the solution add sub-carbonate of potassa, avoiding unnecessary excess: this will throw down the lime and magnesia in the state of carbonates, and leave in solution acetate and nitrate of potassa, and a small portion of carbonate of potassa. Separate the precipitates, evaporate the solution again to dryness, and boil the residuum in alcohol, of .820, which will dissolve the acetate of potassa, and leave the nitrate and sub-carbonate. Separate the spirituous solution, distil it to dryness, and convert the sub-carbonate of potassa into acetate, by pure weak acetic acid. A repetition of the action of the alcohol, will then separate the acetate; and the nitrate of potassa will be left insulated. By the first process, we obtain chloride of silver, from which the whole quantity of muriatic acid is inferred: by the second, sub-carbonate of soda, which denotes the quantity of acid in the muriate of soda: by the third, the carbonates of lime and magnesia, whence we learn the weight of those bases; and from the weight of the nitrate of potassa of the last process, we find the quantity of nitric acid. From these data, the proportions of the several salts in the mixture may be estimated.

100 chloride of silver, are equivalent to	25.46 muriatic acid.
100 nitrate of potassa, are equivalent to	52.88 nitric acid.
100 sub-carbonate of soda, are equivalent to	110. common salt; or
	63.7 muriatic acid.
100 carbonate of lime, are equivalent to	56. lime.
100 carbonate of magnesia, are equivalent to	47. magnesia.

The quantities of lime and magnesia, which saturate equal portions of muriatic and nitric acids, are as follows:

100 parts of nitric acid, saturate	52.5 lime.
100 " " " "	36.5 magnesia.
100 parts of muriatic acid, saturate	192. lime.
100 " " " "	72.3 magnesia.

The substances, soluble in water only, are more numerous than the preceding: they amount to 18, viz., the sulphate of soda, magnesia, ammonia, iron and copper, and alum; nitrate of potassa, the muriates of potassa and soda; the borate of soda and boracic acid. They may be detected by the methods already mentioned, among the preliminaries to the analysis of mineral waters.*

The sulphates of ammonia, iron and copper, alum, nitrate, muriate, and carbonate of potassa, borax and boracic acid, are very rarely found in mineral waters, and carbonate of soda or potassa is incompatible with sulphate of copper, and free boracic acid. Thus the sulphates of soda and magnesia, common salt, and carbonate of soda, are almost the only substances of this class likely to be met with; moreover, only three of them can exist together, for sulphate of magnesia, and carbonate of soda, mutually decompose each other.

Suppose first, that there is no sulphate of magnesia in the water; treat the mixture with successive portions of alcohol, of the sp. gr. .875, which will dissolve all the common salt; then, adding acetic acid to the sulphate and carbonate of soda, the latter will be converted into an acetate, soluble in alcohol, and thus easily separated from the sulphate;—the quantity of acetate will give that of the carbonate.

Secondly, suppose that there is no carbonate of soda present; the common salt is to be separated as before, by alcohol; then dissolve the residuum in water, and add muriate of baryta, until it produces no farther precipitate, taking great care not to add it in excess. The sulphates of soda and magnesia will be decomposed, insoluble sulphate of baryta will fall, and the muriates of soda and magnesia will remain in solution. Evaporate the liquid to dryness, and calcine the residuum in a platinum crucible, at a red heat. The muriate of magnesia will thus be deprived of its acid, and the common salt may be separated from the magnesia by water. 100 parts of common salt are equivalent to 58.25 of soda. From the quantities of soda and magnesia, the quantities of their sulphates may be estimated; and the weight of the sulphuric acid from that of the sulphate of baryta.

If a mineral water contain a hydro-sulphuret, the gases are collected as before stated; the carbonates of lime and magnesia, the sulphate of lime and the silica, must also be separated by the usual methods, except that it is better to evaporate the water in a flask, than in a basin, to prevent the action of the air on the hydro-sulphuret.

To ascertain the quantity of the hydro-sulphuret, (or sulphuretted hydro-sulphuret) introduce the water into a tubulated retort, having a safety tube fitted to the tubulure, and a common tube to its neck, which passes into a flask, containing acetate of lead; pour acetic acid into the water, through the safety tube, and heat it gradually, until it boils. The hydro-sulphuret will be decomposed; its sulphuretted hydrogen will pass into the flask, and produce sulphuret of lead, and the sulphur, which was united with the hydro-sulphuret, will be precipitated. From the weight of the sulphuret, we obtain that of the sulphuretted hydrogen, and from the weight of the latter and the sulphur, that of the sulphuretted hydro-sulphuret. 100 of lead, combine with 15.5 of sulphur, and 16 of sulphur with 1 of hydrogen. The sulphuretted hydro-sulphurets (hydroguretted sulphurets) are probably formed of two equivalents of sulphur, one of hydrogen, and one of base; thus, if it be the sulphuretted hydro-sulphuret of soda, (or more properly of sodium) its composition would be sodium 24, sulphur 32, hydrogen 1, = 57.

The carbonate of soda may be determined by a similar process. After boiling the water, to throw down the insoluble precipitates, filter, and treat it with muriatic acid, in an apparatus like that described for ascertaining the proportion of free carbonic acid, when associated with sulphuretted hydrogen in a water (page 27;) from the weight of the carbonate of lime, that of the alkaline salt will be deduced. 100 parts of carbonate of lime are equivalent to 105.5 parts of sub-carbonate of soda, deprived of its water by a red heat; and to 168 parts of the crystalline bi-carbonate.

* No notice is here taken of the hydriodates and hydro-bromates of potassa and magnesia, which hitherto have been merely detected in mineral waters, and whose separation from their concomitant ingredients, has not yet received the attention of chemists.

† It is recommended, sometimes, to determine the quantity of the base of the sulphuretted hydro-sulphuret, in a direct manner, in preference to deducing it from the weight of the sulphuretted hydrogen and the sulphur, particularly as the latter is difficult to collect.

It remains to consider how the other substances are to be separated. If carbonate of soda be present, the water can contain besides, only the carbonates of lime and magnesia, silica, hydro-sulphuret of soda, and other salts with base of that alkali. In that case, an excess of nitric acid is added, and the solution evaporated to dryness: the residue is calcined at a red heat, water is added, and the liquor filtered. The soda of the carbonate and hydro-sulphuret, and the other salts, (generally only sulphate and muriate of soda) will be dissolved. To the solution, sub-carbonate of ammonia is added, to convert the soda completely into sub-carbonate; and the liquid is boiled, to drive off the excess of the volatile carbonate: we then learn the quantities of common salt and sulphate of soda by alcohol and acetic acid, as directed above. At the same time, the quantity of acetate must be ascertained, which will give that of the soda, and the quantities of carbonic acid and sulphuretted hydrogen, those of the hydro-sulphuret and sub-carbonate.

If no carbonate of soda be present, a mineral water may contain, in addition to the substances mentioned in the last paragraph, the sulphates, muriates, and nitrates of lime and magnesia. In this case, a portion of it is agitated with an excess of chloride of mercury, (calomel) which will decompose the hydro-sulphuret, and form an insoluble black sulphuret of mercury, and muriate of lime or soda, according as the sulphuretted hydrogen was united to one or other of these two bases, will be formed. The rules already given, will enable us to complete the analysis; but, from the quantity of muriate obtained, must be deducted that which arises from the action of the hydro-sulphuret on the chloride of mercury. For this purpose, take a fresh portion of the water, add nitric acid, and boil it to expel the sulphuretted hydrogen; then filter, and drop in an excess of sulphate of silver. The weight of the chloride of silver that will be formed, will indicate the real quantity of the acid contained in the water, whence that arising from the calomel may be estimated. Since the sum of the two quantities has been given by the first experiment, and the quantity of acid derived from the chloride is also known, the quantity of base which saturates it is likewise obtained. The quantity of hydro-sulphuret will likewise be found from the same data, as it is the result of the union of that base with the sulphuretted hydrogen.

Dr. Murray's formula for the analysis of mineral waters.

According to the ingenious views of Dr. Murray, the alkaline bases are united in mineral waters with those acids, with which they form the most soluble compounds; and the insoluble salts, obtained by evaporation, are the products of the operation, and not the original ingredients of the water.* For example, though we may obtain from a mineral water, sulphate of lime and muriate of soda, yet the water in its natural state, held in solution both sulphate of soda and muriate of lime; which, though incompatible salts, when mingled together in dense solution, may yet exist without mutual decomposition, when diffused through a large quantity of fluid. He maintained, therefore, that we obtain a much nearer approximation to the true composition of a mineral water, by disregarding entirely the salts resulting from its evaporation; and instead of this, determining with extreme precision the elements, or acids and bases, of which those salts are composed, and afterwards arranging their mode of combination by the above theory. Having gained a general idea of the nature of any mineral water by ordinary testing, he recommends that we proceed to its minute analysis in the following manner:

Reduce the water, by evaporation, as far as it can be done without occasioning any sensible precipitation or crystallization. Add muriate of baryta as long as it occasions a precipitate, and no longer. By an experiment on a separate quantity, examine whether the precipitate effervesces with dilute muriatic acid, and whether it is entirely dissolved by that acid or not. If entirely soluble, dry and weigh it; and allow 22 grains of carbonic acid for every 100 grains. If it do not effervesce, or dissolve, we may consider it as sulphate of baryta, and reckon that it contains in a dry state, 34 grs. of sulphuric acid in every 100. If it be partly soluble with effervescence, and partly insoluble, it consists both of carbonate and sulphate of baryta; the former of which may readily be separated from the latter, by diluted muriatic acid; and the precipitate being weighed, in a dry state, both before and after the action of the acid, we learn the quantity of each,—what remains being the sulphate only. We have thus expelled the carbonic acid by evaporation, and separated the

* To this opinion there is no objection; though it is probable, that each acid is rather distributed between several bases, than combined exclusively with one of them.

sulphuric acid by the barytic salt: the next object is to discover the kind and quantity of the bases present; and then to find the quantity of muriatic acid originally contained in the water.

To the clear liquid, add a saturated solution of oxalate of ammonia, as long as any turbid appearance is produced. Collect the precipitate, which consists of oxalate of lime: dry it; and by calcining it at a low red heat, convert it into a carbonate, which may be changed into sulphate by a slight excess of sulphuric acid. The sulphate after ignition contains, in 68 parts, 28 of lime, or 41.5 per cent. To separate the magnesia, the clear liquid, remaining after the precipitation of the oxalate of lime, is heated to 100° , and if necessary, reduced a little by evaporation; to it, is then added, first a solution of carbonate of ammonia, and afterwards of phosphate of ammonia, as long as any precipitation takes place, continuing always in the liquor a slight excess of ammonia. The triple phosphate of magnesia and ammonia is thrown down; and this being calcined at a red heat for an hour, is converted into phosphate of magnesia; 100 grs. of the residue are equal to 41.6 of magnesia. To estimate the soda, evaporate to dryness the liquor remaining after the preceding operations, and expose the dry mass to heat as long as any vapors exhale, raising it in the end to redness. The residual matter, is chloride of sodium (common salt); 60 parts of which are equivalent to 24 sodium, 36 chlorine.

It is possible that the chlorine deduced from the residuary common salt, or rather the muriatic acid, which it forms with hydrogen, may exceed the true quantity, and that a part may have been introduced by the muriate of baryta. Or, on the other hand, if muriate of lime or of magnesia were present in the water, the ammonia by which those earths were separated would form, with the muriatic acid detached from those bases, salt, which may have been dissipated by heat; and consequently the chlorine or muriatic acid will have been stated too low. To decide this, the simple rule is, to suppose the elements obtained by the analysis, combined in binary compounds, according to the known proportions in which they unite. The excess or deficiency of chlorine or muriatic acid will then appear; and the amount of the excess being subtracted from the quantity of chlorine or muriatic acid existing in the common salt; or the amount of the deficit being added to that quantity, the real quantity of chlorine or muriatic acid will be apparent. As a check on this operation, it may be proper to estimate directly, the quantity of chlorine or muriatic acid in a given portion of the water, by first abstracting any sulphuric or carbonic acid by nitrate of baryta, and then precipitating the chlorine by nitrate of silver. The real quantity of chlorine, and its equivalent of muriatic acid, will thus be found; and the result will form a check on the other steps of the analysis; for the other ingredients must bear that proportion to the muriatic acid which will correspond with the state of neutralization.

Having thus discovered the different acids and bases, and determined their quantities, it remains to determine the state of combination in which they exist. This is done simply by uniting them in binary compounds in such a manner that the acids and bases may form the most soluble salts. For example, the elements of the salts in a pint of sea water, as determined by Dr. Murray's analysis are,

Lime,	2.9 grs.
Magnesia,	14.8
Soda,	96.3
Sulphuric acid,	14.4
Muriatic acid,	97.7 (= 95.06 chlorine + 2.64 hydrogen.)
	<u>226.1</u>

The compound salts, as obtained by evaporation, are,

Chloride of sodium,	180.5 grs.
Muriate of magnesia,	28.
Sulphate of magnesia,	15.5
lime,	7.1
	<u>226.1.</u>

But the salts existing in a wine-pint of sea-water, in its natural state, before subjecting it to evaporation, may be calculated to be

Chloride of sodium,	180.5 grs.
Muriate of magnesia,	18.3
lime,	5.7
Sulphate of magnesia,	21.6
	<u>226.1.</u>

turbid, the contents are dissolved by means of carbonic acid; the presence of which, is also indicated by small bubbles that rise from the bottom of the well, and burst in the air, on arriving at the surface. But the most evident proof of a spring containing carbonic acid, is the generation of bubbles on the water being shaken, and their bursting with more or less noise, while the air is making its escape. The sediment deposited by the water is likewise to be examined. If it be yellow, it indicates the presence of iron; if black, that of iron combine dwith sulphur. The odor of waters is important in discovering the presence of sulphuretted hydrogen in them; such as contain this substance have the peculiar fetid smell belonging to this gas. The taste of a spring affords useful indications with respect to its contents. Specific gravity is less important in judging of the contents of mineral waters, though it should not always be overlooked.

The examination of waters, by the application of a few reagents, enables us to discover the substances they contain; but to determine the proportions and manner in which they are combined, requires a complete analysis. The former, of these objects, is often all that is sought, in relation to the mineral waters; and when the latter is aimed at, it can be effected only, by first ascertaining all the ingredients that are present. In making these preliminary experiments, the water employed, should, in general, be taken fresh from the spring, or should have been preserved from the air in sealed bottles. Occasionally, however, it needs to undergo an exposure to the air, for the space of a few hours; and when the saline ingredients are not abundant, it sometimes requires to be considerably evaporated. The substances detected by testing, are:

(a.) *Carbonic acid*.—When this is not combined with any base, or not with sufficient to neutralize it, the addition of lime or barytic water, in excess, will throw down a precipitate, soluble with effervescence in muriatic acid. It reddens litmus faintly, when fresh, but loses this property after boiling, or long exposure to the air; and, if litmus has been reddened by it, the color is discharged by boiling.

(b.) *Mineral acids*, when present, uncombined, in water, reddens litmus permanently, even though the water has been boiled.

(c.) *Sulphuretted hydrogen* exhales its peculiar odor, blackens paper moistened by solution of lead or bismuth, and precipitates the nitrate of silver black or brown; but it loses these properties by being boiled.

(d.) *Hydro-sulphuret*, with excess of gas, is attended with the same smell as sulphuretted hydrogen, but weaker; it also precipitates solutions of lead and silver black; but heat does not destroy either of these properties.

(e.) *Alkalies and alkaline, and earthy carbonates* are distinguished by the following tests.—The infusion of turmeric, or paper stained with turmeric, is rendered brown by alkalies, or reddish brown, if the quantity be minute. Paper stained with the infusion of Brazil wood, is rendered blue; but this change is produced also by the alkaline and earthy carbonates. Litmus paper, reddened by vinegar, is restored to its original blue color; a change is produced by the alkaline and earthy carbonates also. When these changes are fugacious, we may conclude that the alkali is ammonia. Fixed alkalies exist in waters that occasion a precipitate with muriate of magnesia after being boiled. The volatile alkali may be distinguished by the smell, or by white fumes with muriatic acid; or it may be obtained in a receiver, by distilling a portion of the water gently, and then it may be distinguished by the above tests. Earthy (as well as metallic) carbonates are precipitated by boiling the water containing them; except the carbonate of magnesia, which is precipitated but imperfectly.

(f.) *Iron*.—Tincture of galls imparts, to water containing iron, a purple or black color. If the tincture have no effect on water after boiling, though it colors it before, the iron is in the state of a carbonate. When the iron is a little oxidized, the presence of lime, facilitates the application of this test; but when on the contrary, the iron is much oxidized, lime prevents the ordinary action of the test. Ferro-cyanate of potassa occasions a blue precipitate in water containing iron. If an alkali be present, however, the blue precipitate does not appear, unless the alkali is first saturated with an acid.

(g.) *Copper*.—Ammonia gives to water, containing any of the salts of copper, a blue tinge; and if the solution is strong, a plate of clean iron, immersed in them, comes out covered with a thin coat of copper.

(h.) *Sulphuric acid* exists in waters that form a precipitate, with the following solutions:—muriate, nitrate, or acetate of baryta, strontia, or lime, or nitrate or ace-

tate of lead. Of these, the most powerful by far, is muriate of baryta, which should be applied with the following precautions: the muriate must be diluted; the alkalies, or alkaline carbonates, if the water contain any, must be previously saturated with muriatic acid; the precipitate must be insoluble in muriatic acid; if boracic acid be suspected, muriate of strontia must be tried, which is not precipitated by boracic acid. The hyro-sulphurets precipitate barytic solutions, but their presence is easily discovered by the smell.

(i.) *Muriatic acid* is detected by nitrate of silver, which occasions a cloud or a white precipitate. To render this test certain, the alkalies, or carbonates, must be first saturated with nitric acid; and sulphuric acid, if present, must be previously removed by means of nitrate of baryta. The precipitate must be insoluble in nitric acid.

(j.) *Hydriodic acid* is detected, by adding to the water, rendered dense by evaporation, in the first place, a solution of starch, and then a few drops of sulphuric acid; the starch assumes a deep blue color. Solution of muriate of platinum causes a deep brownish red color, and, in a few hours, the liquid is covered by a metallic film.*

(k.) *Hydro-bromic acid* is detected in mineral waters, by passing a current of chlorine gas through the water, first rendered dense by evaporation: it assumes a deep orange yellow color, and by adding to it pure sulphuric ether, and agitating the fluids together, the yellow color disappears from the aqueous solution, and rises in the ether to the top of the fluid, which it colors of a rich, reddish brown color.

(l.) *Nitric acid* is detected, by adding sulphuric acid to a portion of the water in which it exists, in quantity abundantly sufficient to decompose all the salts subject to its action, and boiling such acidulated water in a Florence flask, with a leaf of gold, for half an hour, or an hour: the gold will, either in part, or wholly, disappear; and the solution obtained, will give, on the addition of proto-muriate of tin, a deep purple tint; also, by adding to a portion of the water a solution of potassa, till no further precipitate falls down, and then filtering and evaporating the supernatant liquid; a residuum will be obtained, which scintillates when thrown on burning coals.

(m.) *Boracic acid* is detected, by means of acetate of lead, with which it forms a precipitate, insoluble in acetic acid. But, to render this test certain, the alkalies and earths must be previously saturated with acetic acid, and the sulphuric and muriatic acids removed, by means of acetate of strontia and acetate of silver.

(n.) *Baryta* is known by the insoluble white precipitate, which it forms with diluted sulphuric acid.

(o.) *Lime* is detected by means of oxalic acid, which occasions a precipitate in water, containing a very minute proportion of this earth. To render the test decisive, however, the mineral acids, if any be present, must be previously saturated with an alkali; and baryta, if any be present, must be removed by means of sulphuric acid. Oxalic acid precipitates magnesia, but very slowly, whereas it precipitates lime instantly.

(p.) *Lithia* is detected in mineral waters, in the following manner:—into the mineral water, pour a solution of phosphate of soda, evaporate to dryness, and redissolve all that is soluble by cold water. Lithia, if present, is left in the state of an insoluble phosphate of lithia and soda.

(q.) *Magnesia and alumina*.—The presence of these earths is ascertained by the following tests:—ammonia precipitates them both, provided the carbonic acid has been previously separated by a fixed alkali, and boiling. Lime water precipitates only these two earths, provided the carbonic acid be previously removed, and the sulphuric acid also, by means of nitrate of baryta. The alumina may be separated from the magnesia, after both have been precipitated together, either by boiling the precipitate in potassa, which dissolves the alumina, and leaves the magnesia; or the

* M. Ballard's mode of testing for iodine.—After having mixed the liquid containing the iodine, with the starch and the sulphuric acid, a small quantity of aqueous solution of chlorine is to be added, which, from its lightness, may be made not to mix with the mixture, but float on the surface; at the place, where they touch, a blue zone will be perceived, which, however feeble it may be, is readily seen by contrast with the neighboring limpid liquids; if a part of the mixture be slightly agitated, the blue color will be developed when the two solutions are in contact; but if the whole be mixed, it will entirely disappear, if the chlorine be in excess.

precipitate may be dissolved in muriatic acid, precipitated by an alkaline carbonate, dried in the temperature of 100° , and then exposed to the action of diluted muriatic acid, which dissolves the magnesia, without touching the alumina.

(r.) *Silica*, may be ascertained, by evaporating a portion of water to dryness, and redissolving the precipitate in muriatic acid: the silica will remain behind untouched.

By these means, the substances found in mineral waters, may be detected; but as they are generally combined, so as to form salts, it remains to point out the methods for discovering what these combinations are.

1. *Sulphates*.—When we have detected sulphuric acid, combined, and one base or more, in a water, the next step is to ascertain the species of the sulphate. The number of sulphates, hitherto observed in water, is seven; but as one of these, sulphate of copper, is never found, except in the vicinity of copper mines, it may be left out of the question, in our ordinary researches.

Sulphate of soda, or sulphate of potassa, may be detected by the following method:—To free the water of all earthy sulphates, it is evaporated to one half, and lime water added as long as any precipitate appears. The only remaining earthy sulphate will be sulphate of lime, which is separated by evaporating the liquid till it becomes concentrated, and then dropping into it a little alcohol, and after filtration, adding oxalic acid in small quantities. With the water, thus purified, is mingled a solution of lime. If a precipitate appear, either immediately, or on the addition of a little alcohol, it is a proof that sulphate of potassa, or of soda, is present. Which of the two, may be determined by mixing some of the purified water considerably reduced in bulk, by evaporation, with a solution of muriate of platinum. If the alkali be potassa, a yellow precipitate will fall; but none will appear if the alkali be soda.

Sulphate of lime may be detected by evaporating a quart of the water, suspected to contain it, to a few ounces. A precipitate appears, which if it be sulphate of lime, is soluble in 500 parts of water; and the solution affords a precipitate with the muriate of baryta, oxalic acid, carbonate of magnesia and alcohol.

Alum may be detected by mixing carbonate of lime with the water in which it exists; if a precipitate appear, it indicates the presence of alum, or at least of sulphate of alumina; provided the water contains no muriate of baryta or metallic sulphates. The first is incompatible with alum, the second may be removed by the alkaline prussiates. When a precipitate is produced in water by muriate of lime, carbonate of lime, and muriate of magnesia, we may conclude that it contains alum or sulphate of alumina.

Sulphate of magnesia may be known by the following tests;—a solution of carbonate of ammonia (prepared with a portion of that salt which has been exposed) is added to the water, much reduced by evaporation; after which phosphate of soda is added, which will throw down a precipitate of the ammoniaco-magnesian phosphate. A neat mode of applying this test was practiced by Dr. Wollaston, its inventor, as follows:—upon a piece of glass, the clear solution containing magnesia is spread so as to form a thin film, to which are added a few drops of carbonate of ammonia, and phosphate of soda in succession: the word magnesia, or any other, is then traced upon the glass so covered, with the end of a glass rod. The word which is traced will appear in white characters. Objections have been made to these tests however, by Mr. R. Phillips, on the ground of the presence of carbonate of lime in all sesquicarbonate of ammonia, which may cause in the addition of phosphate of soda, a precipitate of phosphate of lime as well as one of the ammoniaco-magnesian phosphate. Hence the original test, made use of by Kirwan, is perhaps to be preferred. Hydro-sulphuret of strontia added to a water containing sulphate of magnesia occasions an immediate precipitate with this salt and with no other, provided the water be previously deprived of alum, if any be present, by means of carbonate of lime, and provided, also, that it contain no uncombined acid.

Sulphate of iron is inferred, if a solution of nut-galls or of ferro-cyanate of potassa, continue to produce their usual ferruginous reaction after the water has been boiled and filtered.

2. *Muriates*.—The most common by far is muriate of soda, which, when it is not accompanied by a great variety of substances, may be very conveniently detected by crystallization. For this purpose a portion of the water is evaporated by a very gentle heat, not exceeding 80° or 90° . As soon as a pellicle appears in the solution, it may be removed, and cautiously dried on bibulous paper, and exam-

ined with a magnifier: the cubical form of the crystal belonging to this salt will generally be discoverable. When numerous salts, however, are contained in the same solution, it may sometimes be difficult to detect its presence in this way. In such cases, the combined muriatic acid must be sought for by a solution of nitrate of silver, taking care to add in the first place a few drops of nitrate of baryta, and allowing the precipitate to subside: * if now, on the addition of the solution of silver a precipitate take place, a muriate may be inferred with certainty,—but whether it be of soda, potassa, lime, or magnesia, or of several of these, is not certain.

Separate tests must be applied for these; and the alkalies, when present, may be distinguished from each other, by the peculiar salts which they form with the different acids. With tartaric acid, soda forms a soluble salt; while with potassa, an acidulous tartrate is formed, of comparatively sparing solubility. Muriate of platinum affords a still more delicate test, as has been noticed above.

Muriate of baryta may be detected by sulphuric acid, as it is the only barytic salt hitherto found in water.

Muriate of lime may be detected by the following method:—Free the water from sulphate of lime, and other sulphates, by evaporating it from a considerable bulk to a few ounces, mixing it with alcohol, and adding last of all nitrate of baryta, as long as any precipitate occurs. Filter the water; evaporate to dryness; treat the dry mass with alcohol; evaporate the alcohol to dryness, and dissolve the residuum in water. If this solution give a precipitate with acetate of silver and oxalic acid, it may contain muriate of lime. It must in that case, contain it if after being treated with carbonate of lime, it give no precipitate with ammonia. If the liquid in the receiver give a precipitate with nitrate of silver, muriate of lime existed in the water.

Muriate of magnesia may be detected by separating all the sulphuric acid, by nitrate of baryta. The clear fluid, separated from the precipitate, is evaporated to dryness, and the residuum treated with alcohol. The alcoholic solution is then evaporated in turn, and the dry residue dissolved in water. The muriate of magnesia, if the water contained any, will be found in this solution. Let us suppose, that by the tests formerly mentioned, the presence of muriatic acid, and of magnesia, in this solution, has been ascertained. In that case, if carbonate of lime afford no precipitate, and if sulphuric acid and evaporation, together with the addition of a little alcohol, occasion no precipitate, the solution contains only muriate of magnesia. If these tests give precipitates, we must separate the lime which is present, by sulphuric acid and alcohol, and distil off the acid with which it was combined. Then the magnesia is to be separated by the oxalic acid and alcohol, and the acid with which it was united is to be distilled off. If the liquid in the retort give a precipitate with nitrate of silver, the water contains muriate of magnesia.

8. *Nitrates*.—These seldom occur in waters. When they do, they may be detected in the following manner:—Alkaline nitrates may be discovered by having the water examined for sulphuric acid by means of acetate of baryta, and for muriatic acid by acetate of silver. The filtered liquor is evaporated to dryness, and the dry mass treated with alcohol. What the alcohol leaves undissolved, must consist only of the alkaline nitrates, and acetate of lime. It is dissolved in water; and carbonate of magnesia added, which will occasion a precipitate if lime be present. The lime is separated by farther additions of carbonate of magnesia. The liquid is filtered, evaporated to dryness, and the residuum treated with alcohol. The alcohol now leaves only the alkaline nitrates, which may easily be recognized by their respective properties. Nitrate of lime is detected by concentrating the water, and mixing it with alcohol to separate the sulphates. The liquid is filtered and the alcohol distilled off; the muriatic acid is then separated by the addition of acetate of silver. The solution is filtered, evaporated to dryness, and the residuum dissolved in alcohol. The alcoholic solution is evaporated to dryness, and the dry mass dissolved in water. If this last solution indicates the presence of lime by the usual tests, the water contained nitrate of lime.

To detect nitrate of magnesia, the water is to be freed from sulphates and muriates, as above. The liquid thus purified, is to be evaporated to dryness, and the re-

* The nitrate of silver being decomposed by the sulphuric acid.

15. *Sulphuret of Silicium*.—Sefström has found that silica heated in his blast furnace in a charcoal crucible can be reduced by sulphuretted hydrogen to a sulphuret of silicium. It is easily volatilized, and in burning gives off the peculiar sublimate of silica, which has been repeatedly noticed before.—*Idem*. p. 379.

16. *Artificial Ultramarine*.—Pulverized quartz is to be fused with four times its weight of carbonate of soda, the mass dissolved in water and then precipitated by muriatic acid; thus a hydrate of silica will be formed. A hydrate of alumina is to be prepared by precipitating alum by ammonia. These two earths are to be carefully washed with boiling water; the proportion of dry earth in each is then to be ascertained by heating a small quantity and weighing it. The hydrate of silica used by M. Gmelin, the discoverer of the process contained 56 per cent. and the hydrate of alumina 3.24 per cent. As much hydrate of silica is then to be dissolved in a hot solution of caustic soda as it will take up, and the quantity determined; then such proportion is to be taken as contains 72 parts of anhydrous silica and a quantity of the hydrate of alumina, equivalent to 70 parts of dry alumina added to it, and the whole evaporated together, being continually stirred, until it becomes a damp powder.

This combination of silica, alumina, and soda is the basis of the ultramarine, and is now to be colored by a sulphuret of sodium, in the following manner. A mixture of two parts of sulphur, with one part of anhydrous carbonate of soda, is to be put into a hessian crucible, covered up and then gradually raised to a red heat until it is well fused; then the mixture is to be thrown in very small quantities at a time into the fused mass. As soon as the effervescence occasioned by the water in one portion has ceased, another portion is to be added. Having retained the crucible at a moderate red heat for an hour, it is to be removed from the fire and allowed to cool. It now contains ultramarine, mixed with excess of sulphuret: the latter may be separated by water. If sulphur is in excess, a moderate heat will dissipate it. If all the parts are not equally colored a selection should be made, and then the substance reduced to fine powder.—*Ann. de Chim.* xxxvii. 409.

17. *New process for obtaining Lithia*.—M. Quesneville Jun. gives the following as a good method of separating lithia. Take one part of apodumene, levigated, and mix it accurately with two parts of powdered litharge: put the mixture into a crucible and expose it to a white heat. In about a quarter of an hour, the mass is perfectly fluid: when cool, it is finely powdered and nitric acid is added to it for the separation of the silica; the nitrate of lead is precipitated by sulphuric acid, and the solution evaporated to dryness to expel all the nitric acid. The dry mass is treated with water; and the alumina and other metallic oxides precipitated by ammonia; after which carbonate of ammonia is added to precipitate the lime and magnesia. The solution is then filtered and evaporated to dryness. The residue is strongly heated to expel the ammoniacal salts; this operation must not be performed in a platinum crucible, as it would be acted upon; a porcelain one is therefore employed. The calcined residuum is treated with water, and all the sulphuric acid precipitated by baryta; the filtered liquor when evaporated gives pure lithia.—*Jour. de Pharmacie, Août*. 1830.

18. *Alum with lithia and chrome*.—Kralowanszky has formed a lithia alum, having precisely the same composition as those already known. Fischer has also discovered a chrome alum in which the green oxide of chrome takes the place of the alumina in the other alums. Hence it appears, that lithia is isomorphous with the other alkalies, and the tritoxide of chromium and aluminium are probably isomorphous also.—*Edin. Jour. Science*, No. v, N. 8. p. 24.

19. *Test of potassa by nickel before the blowpipe*.—Dissolve the oxide of nickel in borax by heat, and add to the vitreous matter before the blowpipe a little nitre, feldspar or other body containing potash, and a blue glass is instantly obtained. The presence of soda does not prevent this action. The nitrate or oxalate of nickel may be employed, but it must be ascertained, that cobalt is not present.

20. *Formic acid* is obtained in a state of great purity by distilling alcohol with sulphuric acid and peroxide of manganese; but in order to prevent the formation of sulphuric ether, it is proper to employ weak alcohol, or common brandy.—*Ann. de Chim.* Feb. 1830.

21. *Mellitic acid*.—M. M. Wöhler and Liebig find that mellitate of silver, when dry, gives no trace of water, or a hydrogenous product, by distillation: nor even when burnt by means of oxide of copper. They also find it to be destitute of azote;

for the gaseous products of its composition are totally absorbable by potassa. 0.326 grammes of mellitate of silver = 0.07058 of mellitic acid gave 56 cubical centimetres of carbonic acid gas; from which the composition may be calculated at 50.31 carbon, and 49.79 oxygen per cent. Then calculating, from the known equivalent number of mellitic acid (62.3) the substance would appear to be composed of

4 atoms carbon.	8.05748
8 " oxygen,	8.00000
	<hr/> 6.05748

On comparing the composition of mellitic acid with that of succinic acid, it appears that the only difference is, in the fact that the latter contains hydrogen; and that if the latter be theoretically abstracted, there remain the elements of mellitic acid in true proportions. It is probable therefore, that mellitic acid may be derived from the decomposition of succinic acid, which as we know is often found in fossil wood, although amber is wanting where the mellite is found.—*Ann. de Chim.* xliii. p. 200.

22. *Sesqui-oxide of lead*.—Fischer discovered that red lead dissolves in concentrated acetic acid, giving a clear colorless solution, which in a close vessel undergoes no change. Water decomposes it and throws down a brown oxide. Berzelius, repeating the experiment, found that a small quantity of acid converted the minimum into a colorless salt, while a larger quantity dissolved it. Heat threw down the brown oxide without previous dilution. Hence it is inferred that red lead is not as some have supposed, a compound of two oxides; but a sesqui-oxide of lead.—*Idem*.

23. *Sulphurets of Lead*.—Budberg has shown, that lead has two lower degrees of sulphurization than those formerly known. One of these is obtained when 26 parts of sulphuret of lead (atom to atom,) are mixed with 21.6 of lead in fine grains and melted for 15 minutes under glass of borax. Its fracture is crystalline and scaly, and it is so soft that it can be beaten out under the hammer without breaking. It is a di-sulphuret of lead. The other is obtained by melting the same mixture in the open air without glass of borax. Its fracture is fine grained, it is still more malleable than the former, and it is also sectile. It contains only half as much sulphur as the former. He has shown, also, that the mixed ores known in Germany by the names of stein, bleistein, kupferropestein, dunnestein, &c. contain the protosulphuret of iron combined in exact chemical proportions with the former of these, the di-sulphuret with the di-sulphuret of copper, and occasionally a proportion of zinc. The known sulphurets of lead are, therefore,

The protosulphuret = 1 atom sulphur	+ 1 atom lead, the common galena,
Di-sulphuret = 1	+ 2
Tetrasulphuret = 1	+ 4
	<i>Idem.</i>

24. *Reduction of Sulphuret of Arsenic*.—Liebig has perfected the detection of sulphuret of arsenic. He draws out a fine tube, as for the reduction of arsenious acid by charcoal, drops into it a minute fragment of the sulphuret, and covers it two or three lines deep with carbonized acetate of lime. Immediately on heating it, the arsenic is deposited in the metallic state on the upper portion of the tube.

25. *Fulminating Silver*.—Mitscherlich's mode of preparing this substance is very simple. He dissolves a silver salt in caustic ammonia to saturation, and adds caustic potassa in excess. The fulminating powder falls immediately, and more is obtained by heating till the ammonia is driven off.—*Edin. Jour.* 1830.

26. *Isomorphous Acids*.—Mitscherlich has shown that the sulphuric, selenic, and chromic acids are isomorphous, giving salts of the same form where the bases and the quantity of water is the same.

27. *New Chromic Acid*.—This green acid, described by Koechlin, is shown by Berzelius to be a bi-tartrate, which, like many other tartrates, is not precipitated by alkalies, but gives with them crystallized double salts.—*Edin. Jour. Science*, No. iv. N. S. p. 19.

28. *Atomic weights of rare Metals*.—According to Berzelius, these weights, determined from the decomposition of the double salts, are as follows:

Platinum and Iridium,	1283.427
Osmium,	1244.22
Rhodium,	651.38
Palladium,	665.784
	<i>Idem.</i>

29. *Oxides of Iridium, Osmium, Rhodium, and Palladium.*—Iridium has 4 oxides:

Protoxide	= 1 iridium	. . . . .	+ 1 oxygen.
Sesqui-oxide	= 2 do.	. . . . .	+ 3 do.
Deutoxide	= 1 do.	. . . . .	+ 2 do.
Tritoxide	= 1 do.	. . . . .	+ 3 do.

Osmium, (whose sp. gr. is about 10,) forms 5 oxides.

Protoxide	= 1 osmium	. . . . .	+ 1 oxygen.
Sesqui-oxide	= 2 do.	. . . . .	+ 3 do.
Deutoxide	= 1 do.	. . . . .	+ 2 do.
Tritoxide	= 1 do.	. . . . .	+ 3 do.
Osmic Acid	= 1 do.	. . . . .	+ 4 do.

Rhodium has two oxides:

Protoxide	= 1 rhodium,	. . . . .	+ 1 oxygen.
Tritoxide	= 1 do.	. . . . .	+ 3 do.

These combine in various proportions, but no distinct deutoxide has been obtained. Palladium has two oxides:

Protoxide	= 1 palladium	. . . . .	+ 1 oxygen.
Deutoxide	= 1 do.	. . . . .	+ 2 do.

Idem.

30. *Carburets, Sulphurets, and Phosphurets of Iridium and Osmium.*—Carbon and iridium combine with great ease, forming a quadri-carburet of iridium.

Sulphurets of iridium are obtained on decomposing the chlorides by sulphuretted hydrogen. They dissolve with ease in nitric acid, forming sulpho-salts. By a red heat they are converted into sub-sulphurets.

Osmium has as many sulphurets as oxides, which may be formed either by the humid or by the dry way. Those with less sulphur, obtained by precipitation are yellow, and partly soluble in water: that with the most sulphur is thrown down completely from an acid solution.

Iridium and osmium combine with phosphorus. The phosphate of iridium is grey that of osmium resembles the metal, but is not volatile; leaving, when heated a sub-sulphate of osmium.—*Idem.*

31. *Salts of Iridium, Osmium, Rhodium, and Palladium.*—Iridium unites with chlorine in four proportions, forming a chloride, a sesqui-chloride, a bi-chloride, and a ter-chloride, analogous to the oxides. Berzelius has formed and analyzed a series of double salts, constituted as follows:

1 atom chloride of potassium	. . . . .	+ 1 atom chloride of iridium.
1 do. do. ammonium,*	. . . . .	+ 1 do. do. do.
1 do. do. potassium,	. . . . .	+ 1 do. sesqui-chloride of do.
1 do. do. do.	. . . . .	+ 1 do. bi-chloride do.
1 do. do. ammonium,*	. . . . .	+ 1 do. do. do.
1 do. do. sodium,	. . . . .	+ 1 do. of iridium, + 6 water.
1 do. do. potassium,	. . . . .	+ 1 ter-chloride of iridium.

The fourth of these is the common double salt formerly known.

Osmium combines with chlorine in the same proportions as iridium, and forms double salts of the same appearance, and composition as those above mentioned.

The red double salts of rhodium with potassium and sodium, are unlike in composition. They are composed of

3 chloride of sodium	+ 1 terchloride of rhodium	+ 18 water.
2 do. potassium,	+ 1 do. do.	+ 1 do.

Of Palladium, Berzelius has formed two new double salts, consisting of

1 atom chloride of potassium,	+ 1 bi-chloride of palladium.
1 do. do. ammonia,	+ 1 chloride do.

The latter compound is obtained by treating chloride of palladium with caustic ammonia, and evaporating.—*Idem.*

32. *On the production of magnetism by Friction.*—Friction has long been known to be capable of producing magnetism, but it was not supposed to be efficacious, unless upon iron, either magnetized or in a neutral state. M. Haldat has, however, found that all hard bodies may, by means of friction, assist in the decomposition of the

* Prof. Berzelius admits this base, which has not been recognized by most chemists.

magnetic fluid, if their action is promoted by the combined action of magnets, which by themselves, are incapable of producing it. To prove this, take a piece of soft iron wire about 4 inches long and 1-25th of an inch in diameter. If this wire is placed horizontally between two bar magnets, with their opposite poles facing one another, and at such a distance that it cannot be magnetized, it will receive distinct magnetism by friction with all hard bodies, such as copper, brass, zinc, glass, hard woods &c.—*Ann de Chim.* xlii. p. 41.

33. *Carbonate and acetate of Copper.*—Gay-Lussac has shown that the black powder obtained from the carbonate, and the brown from the acetate, by boiling in water, are only oxide of copper.—*Idem.* Vol. xxxviii. p. 385.

34. *Notices of Iodine and Bromine in the United States.*

The first published notice that I have met with of the discovery of iodine in this country, is contained in the American Journal, Vol. xvi, postscript to No. 1. It is stated by Prof. Griscom, that Dr. William Usher obtained the characteristic blue color, by adding a solution of starch and a little sulphuric acid to the water of the Congress spring, Saratoga, evaporated to one twelfth of its volume; a solution of chlorine discharged the color.

In the 2d No. of the same volume of the American Journal, Dr. J. H. Steel, of Saratoga springs, published an analysis of the above water, in which he states its composition as being muriate of soda 297.3 grs., hydriodate of soda 3., carbonate of soda 19.21, carbonate of lime 92.4, carbonate of magnesia 23.1, oxide of iron 5.39, with a minute proportion of silica and alumina.

Iodine was discovered by Prof. J. P. Emmet, Univ. of Virginia, in the Kenawha saline waters, Virginia; it exists in small proportion.*

Bromine.—I believe that the first instance in which bromine was discovered in this country was by myself, in the bittern of Salina, New York; it exists apparently in considerable proportion in that water.†

Bromine was discovered also by Mr. A. A. Hayes, in the waters of Saratoga springs, the same that had afforded the iodine to Dr. Usher and to Dr. Steel. The bromine is in very small quantity, and Mr. Hayes proposes the following method of detecting iodine and bromine. A few drops of pure water are mixed, in a conical glass, with a drop of sulphuric acid and half a volume of cold solution of starch; a few bubbles of chlorine are then passed through the mixture and the starch is allowed to subside. A glass rod, dipped in the fluid to be examined, being brought to the surface of the fluid in the glass, dense orange colored striz descend from the rod and rest for some time on the starch, if bromine alone be present; if there is iodine also, there are additional striz of deep blue; in a few seconds the blue disappears and the yellow of the bromic solution remains; very minute quantities can thus be discovered.‡

Bromine, in considerable quantity, was discovered by Prof. Emmet, in the Kenawha water, that contained the iodine already mentioned.

Test for bromine in saline waters.—Evaporate and crystallize most of the salts, and place some of the filtered fluid in a narrow tube; add a few drops of strong liquid chlorine, and an orange color will be perceived, which finally vanishes and disappears; the water should be free from organic matter and chlorine should not be used in excess.—*Loewig's Monograph, Heidelberg*—*Journal of the Philadelphia College of Pharmacy.*

35. *Cold at Melville Island, 74° 47', N. Lat. 110° 48' W. Long. of Gr.*

From November to March, inclusive, the thermometer was occasionally as low as —50° and at some distance from the ship —55°; in October it sank to —28°, and in May to —4°. In January it was never above —2° and in February —17°. It froze during every month. The maximum of July was 60°, from May to Septem-

* Am. Jour. Vol. xviii, p. 260.

† Id. p. 142.

‡ Id. p. 143.

ber inclusive, the maximum was above 32° ; highest observed temperature, 60° , lowest, 50° or 55° , range, 110° or 115° .—T. on H. and E.

	Maximum.	Minimum.		Maximum.	Minimum.
January	— 2°	— 47°	July	+ 80°	+ 32°
February	—17	—50	August	+45	+22
March	+ 6	—40	September	+37	— 1
April	+33	—32	October	+17.5	—28
May	+47	— 4	November	+ 6	—47
June	+51	+23	December	+ 6	—43

36. *Specific heat of mercury.*—Dr. Thomson, (on H. and E.) p. 66, states it at $\frac{1}{3}$ that of water; it has been usually stated at $\frac{1}{13}$ or $\frac{1}{17}$, Vol. I, p. 121, of this work.

37. *Specific heat of gases.**—Under the same pressure, the same volumes of all gases have the same specific heat, and the specific heats of the gases in equal weights, are inversely as their specific gravities.

Gases.	Specific heat.	Gases.	Specific heat.
Oxygen gas	1.	Sulphur vapor	1.
Hydrogen	16.	Sulphuretted hydrogen	0.94118
Carbon vapor	2.66	Muriatic acid	0.86486
Carburetted hydrogen	2.00	Carbonic acid	0.72727
Ammonia	1.6824	Protoxide of azote	0.72727
Steam	1.7778	Cyanogen	0.61538
Phosphorus vapor	1.3333	Sulphurous acid	0.5
Phosphuretted hydrogen	1.2307	Chlorine	0.44444
Hydrocyanic acid vapor	1.1852	Sulphuret of carbon vapor	0.42105
Azotic gas	1.1429	Sulphuric acid vapor	0.4
Olefiant gas	1.1429	Hydriodic acid	0.256
Carbonic oxide	1.1429	Iodine vapor	0.12903
Deutoxide of azote	1.0666		

38. Conducting power of metals.†

	Conducting power.		Conducting power.
Gold	100.	Tin	30.33
Platinum	98.1	Lead	17.96
Silver	97.3	Marble	2.34
Copper	89.82	Porcelain	1.22
Iron	37.41	Brick earth	1.13
Zinc	36.37		

It is obvious that these results are very discordant with previous opinions, and some of them with known facts, such as the slowness with which heat passes through platinum, and the rapidity with which it passes through silver.

39. *Cooling of bodies.‡*—In a perfect vacuum the heat escapes by radiation only; this exists to the same amount in the air which also conducts heat away, and in both cases the rapidity of cooling is influenced by the nature of the surface, which however, does not affect the conducting power of the air or gas. The radiation is the same whatever may be the elastic fluid that surrounds the hot body.

40. *Hoar frost on the inside of windows.*—This is now imputed more to the radiation from the exterior surface of the glass than to the direct cooling effect of the air by mere contact; this deposition, *ceteris paribus*, is the greatest when the shutters are closed, which prevents the return of heat by radiation from other parts of the room.—T. on H. and E.

* Thomson, on the authority of Haycraft, and Marcat, and de la Rive.

† Despretz, Ann. de Ch. et de Ph. Vol. xix, p. 47.

‡ Petit and Dulong.

TABLE OF EXPANSION.*

Substances tried.	Authority.	Dilatation in decimals+ the original length	dil. in vulg. fract.
Antimony	Smeaton	1.00108300	$\frac{7}{23}$
Bismuth	Ditto	1.00139200	$\frac{7}{18}$
Brass	Lavoisier & Laplace	1.00186671	$\frac{3}{23}$
— cast	Smeaton	1.00187500	$\frac{3}{23}$
— wire	Ditto	1.00193000	$\frac{3}{18}$
— 16, tin 1	Ditto	1.00190800	$\frac{3}{24}$
Copper	Lavoisier	1.00172244	$\frac{3}{11}$
— hammered	Smeaton	1.00170000	$\frac{3}{18}$
—	Petit and Dulong	1.00171821	$\frac{3}{23}$
Glass tube without lead (crown)	Lavoisier	1.00087572	$\frac{1}{142}$
— white barom.	Smeaton	1.00083000	$\frac{1}{254}$
—	General Roy	1.00077615	$\frac{1}{237}$
— rod	Ditto	1.00080787	$\frac{1}{237}$
— English flint	Lavoisier	1.00081166	$\frac{1}{238}$
— crown	Ditto	1.00089760	$\frac{1}{114}$
— tube	Petit and Dulong	1.00086130	$\frac{1}{116}$
Gold, Paris standard, not softened	Lavoisier	1.00155155	$\frac{6}{23}$
— pure	Ditto	1.00146606	$\frac{6}{23}$
Iron	Smeaton	1.00125800	$\frac{7}{66}$
—	Petit and Dulong	1.00118203	$\frac{7}{18}$
— cast (prism)	General Roy	1.00110940	$\frac{7}{61}$
— hammered	Lavoisier	1.00122045	$\frac{7}{18}$
— wire	Ditto	1.00123504	$\frac{7}{18}$
Lead	Ditto	1.00284836	$\frac{3}{21}$
Ditto	Smeaton	1.00286700	$\frac{3}{28}$
Pewter, fine	Ditto	1.002283	$\frac{4}{38}$
Palladium	Wollaston	1.0010000	$\frac{1}{258}$
Platinum	Troughton	1.00099180	$\frac{1}{258}$
Ditto	Borda	1.00085655	$\frac{1}{167}$
Ditto	Petit and Dulong	1.0088420	$\frac{1}{131}$
Silver, Paris standard	Lavoisier	1.00190868	$\frac{3}{24}$
Ditto	Troughton	1.0020826	$\frac{4}{26}$
Solder, soft, (lead 2, tin 1)	Smeaton	1.0025080	$\frac{3}{28}$
— spelter, (brass 2, zinc 1)	Ditto	1.0020580	$\frac{4}{28}$
Speculum metal	Ditto	1.00193300	$\frac{3}{17}$
Steel, hard	Lavoisier	1.00107875	$\frac{6}{27}$
— ditto	Smeaton	1.00122500	$\frac{8}{28}$
— soft	Lavoisier	1.00107956	$\frac{6}{28}$
— tempered	Ditto	1.00123956	$\frac{6}{27}$
Tin, Falmouth	Lavoisier	1.00217298	$\frac{4}{28}$
— Malacca	Ditto	1.00193765	$\frac{3}{28}$
— Grain	Smeaton	1.00248300	$\frac{4}{28}$
Zinc	Ditto	1.00294200	$\frac{3}{28}$
— hammered half inch per ft.	Ditto	1.00301100	$\frac{3}{28}$

* N. B.—The linear expansion, by being heated from 32° to 212° Fahr. is here to be understood. The expansion in volume, may be learned, by multiplying the decimal quantities by 3, or dividing the denominators of the vulgar fractions by 3.

Henry

41. *Force of Vapor.*—It is stated pp. 87 and 88, and 105, Vol. I, that the force of vapor formed at the boiling point is the same in all fluids, and just equals the pressure of the atmosphere, that is thirty inches of mercury; this law appears to be fully established.

It was also stated in the same connexion that the force of vapor is the same for every fluid at an equal number of degrees above and below its boiling point. Both these laws were originally given on the authority of Mr. Dalton, which was sustained by that of other eminent philosophers. Dr. Turner, in the second edition of his *Chemistry*, (third Am. p. 61.) says,—“the force of vapor from all liquids is the same, at equal distances above or below the several temperatures at which they boil in the open air. Thus steam at 200° F., has the same elasticity as the vapor of ether at 85°, the boiling point of the former being 212°, and of the latter 97°. Biot and Amédée Berthollet (*Biot. Traite de Ph. I.*, 282.) have found that this law applies exactly to many other liquids; but some experiments on the oil of turpentine and petroleum, would lead to the conclusion that it is not universal.” Dr. Thomson (*On Heat and Electricity*, p. 222.) states that by subsequent experiments, the second law of Mr. Dalton has not been found to hold good, and that it has been relinquished by its author. At the time when my statement of those laws was written and printed, neither the second English edition of Dr. Turner had appeared nor the work of Dr. Thomson, nor the eleventh edition of Henry* in which the correction of the law is thus stated :

“The force of vapor from different liquids varies at the same temperature,” and “the variation of the force of vapor, from all liquids, is the same for the same variation of temperature, reckoning from vapor of any given force;” thus measuring the force of all liquids at the boiling point by thirty inches of mercury, it is found that by losing 30° of heat from 212°, the vapor of water loses half its force, and so the vapor of any other liquid loses half its force, by losing 30° of heat below its boiling point, and so on for any other increment or decrement of heat; this has been experimentally established by Mr. Dalton.

Temperatures by the common thermometer.	Ether vapor, ratio 2, specific gravity .72.	Sulphuret of carbon vapor, ratio 1.978.	Alcohol vapor, ratio 2.7, specific gravity .82.	Acetic acid vapor, ratio 2.57.	Water, ratio 2.602.
	Inch. merc.	Inch. merc.	Inch. merc.	Inch. merc.	Inch. merc.
7°	3.75	3.134	.193	..	.11
35	7.5	6.20	.560	.27	.29
65+	15.	12.26	1.51	.69	.75
97	30.	24.26	4.07	1.77	1.96
133	60.	48.	11.00	4.54	5.07
178	120.	..	29.70	11.7	13.18
220	240.	..	80.2	30.	34.2
272	..	..	..	..	88.9
340	..	..	..	..	231.0

The above is an improved and extended table of the force of vapor. It shows that the different vapors increase in force in geometrical progression, to certain intervals of temperature, the same to most or all liquids. These intervals of temperature were presumed in a former table to be in reality equal to one another; but the accuracy of this last notion has been questioned.

42. *Elasticity of High Steam.*†—Instead of the tables heretofore given in chemical works, I now copy that drawn up by Messrs. Prony, Arago, Gerard and Dulong as the results of very arduous and dangerous experimental investigation undertaken at the instance of the French Government, in relation to the safety of steam boilers.

* Vol. i, p. 128-9 Lond. Edit.

† Ann. de Ch. et de Ph. xliii, 74.

The following table exhibits the elasticity of steam at various temperatures, till it amounts to 24 atmospheres. An atmosphere is measured by a column of mercury of 29.922 inches (0.76 metre), which has been adopted in France as the mean height of the barometer at the surface of the sea.

<i>Elasticity of steam, the pressure of the atmosphere being 1.</i>	<i>Corresponding temp. in deg. of Fahrenheit.</i>	<i>Elasticity of steam, the pressure of the atmosphere being 1.</i>	<i>Corresponding temp. in deg. of Fahrenheit.</i>
1	212°	13	390.66°
1½	234	14	386.94
2	250.5	15	392.86
2½	263.8	16	398.48
3	275.2	17	403.83
3½	285	18	408.92
4	293.7	19	413.78
4½	300.3	20	418.46
5	307.5	21	422.96
5½	314.24	22	427.28
6	320.36	23	431.42
6½	326.26	24	435.56
7	331.7		
7½	336.86	25	439.34
8	341.78	30	457.16
9	350.78	35	472.73
10	358.88	40	486.59
11	366.85	45	499.14
12	374	50	510.6

The last six temperatures in the table are deduced by calculation.

This table of the French Academicians constitutes a precious addition to our knowledge of the elasticity of steam. The experiments, which were conducted by Dulong and Arago, constitute some of the most difficult and even dangerous for which science is indebted to the zeal and intrepidity of philosophers. Mercury, by the elasticity of the steam, was forced up a tube of glass to the height of 42.6517 feet. The diameter of the tube was 0.1968 inches. They took the opportunity of subjecting common air to the pressure of from 1 to 24 atmospheres, and found that the Boylean law, namely, that the bulk diminishes as the pressure increases, holds as far as twenty-four atmospheres.—*Dr. Thomson on Heat and Electricity.*

For the entire report, see Ann. de Ch. et de Ph. Vol. XLIII. p. 74, before cited.

TABLE OF AFFINITIES.

OXYGEN. Metallic bases of the alkalies and earths. Carbon Manganese Zinc Iron Tin Hydrogen Antimony Phosphorus Sulphur Arsenic Cobalt Nickel Copper Bismuth Mercury Silver Gold Platinum	Muriatic Phosphoric Fluoric Oxalic Tartaric Arsenic Succinic Citric Benzoic Sulphurous Acetic Saccho-lactic Boracic Nitrous Carbonic Prussic Oil Water Sulphur	Sulphuric Tartaric Succinic Phosphoric Saccho-lactic Nitric Muriatic Fluoric Arsenic Citric Benzoic Acetic Boracic Sulphurous Nitrous Carbonic Prussic Sulphur	Soda Baryta Strontia Lime Ammonia Magnesia Alumina Metallic oxides	Ammonia Alumina Metallic oxides
				ACETIC ACID. Baryta Potassa Soda Ammonia Lime Magnesia Alumina Metallic oxides
			SULPHURIC ACID. Baryta Strontia Potassa Soda Lime Magnesia Ammonia Alumina Metallic oxides	PRUSSIC ACID. Potassa Soda Ammonia Lime Baryta Strontia Magnesia Alumina Metallic oxides
	MURIATIC. Acids Sulphuric Oxalic Succinic Fluoric Phosphoric Saccho-lactic Nitric Muriatic Citric Tartaric Arsenic Benzoic Acetic Boracic Sulphurous Carbonic Prussic Sulphur	MAGNESIA. Acids Oxalic Phosphoric Sulphuric Fluoric Arsenic Saccho-lactic Succinic Nitric Muriatic Tartaric Citric Benzoic Acetic Boracic Sulphurous Carbonic Prussic Sulphur	SULPHUROUS ACID. Baryta Strontia Lime Potassa Soda Magnesia Ammonia Alumina Metallic oxides	ALCOHOL. Water Ether Volatile Oils Ammonia Fixed alkalies Sulphur Muriates
NITROGEN. Oxygen Hydrogen				ETHER. Alcohol Volatile oils Water
HYDROGEN. Oxygen Sulphur Carbon Phosphorus Nitrogen				VOLATILE OILS. Ether Alcohol Fixed oil Fixed alkalies Sulphur
CARBON. Oxygen Iron Hydrogen				FIXED OILS. Lime Metallic oxides Ether Volatile oil Fixed alkalies Volatile alkalies Sulphur
SULPHUR. Oxygen Potassa Soda Iron Copper Tin Lead Silver Bismuth Antimony Quicksilver Arsenic Molybdenum Tellurium				
AMMONIA, POTASSA & SODA. Acids Sulphuric Nitric	STRONTIA. Acids Sulphuric Phosphoric Oxalic Tartaric Nitric Muriatic Succinic Acetic Arsenic Boracic Carbonic Sulphur	ALUMINA. Acids Sulphuric Nitric Muriatic Fluoric Arsenic Oxalic Tartaric Phosphoric Acetic	ACIDS, PHOSPHORIC, FLUORIC, BORACIC, OXALIC, TARTARIC, ARSENIC, CITRIC, BENZOIC, SUCCLINIC, SACCHOLACTIC. Lime. Baryta Strontia Magnesia Potassa Soda Ammonia Alumina Metallic oxides	
		SILICA. Fluoric Acid Potassa	CARBONIC ACID. Baryta Strontia Lime Fixed alkalies Magnesia	
	LIME. Acids Oxalic	ACIDS, NITRIC, NITROUS and MURIATIC. Potassa		

Murray's Elements.

CHEMICAL EQUIVALENTS.

Acid, acetic, (51 Prout)	80	Barium, iodide,	194
c. 1w.	59	protoxide, (baryta)	46
arsenic, (a. 38+ox. 30 Berz.)	58	peroxide,	86
arsenious, (a. 38+ox. 12 Berz.)	60	sulphuret,	85.71
benzoic	120	sulphuret,	86
boracic, (b. 8+ox. 16)	94	Bismuth,	73
c. 2w.	42	chloride,	108
bromic, (b. 75+ox. 40)	115	oxide,	80
carbonic, (carb. 6+ox. 16)	22	iodide,	196
chloric, (chl. 36+ox. 40)	76	phosphuret,	87.71
chloriodic, (chl. 72+iod. 124)	? 196	sulphuret,	88
chlorocarbonic, (chl. 36+carb. oxide 14)	80	Boron,	8
chloro-cyanic, (chl. 36+cyan. 26)	62	Bromine,	? 75
chromic, (chr. 32+ox. 20)	83	Cadmium,	86
citric,	88	chloride,	92
c. 2w.	76	oxide,	64
columbic,	? 209	iodide,	180
fluoboric,	? 68	phosphuret,	71.71
formic,	37	sulphuret,	73
fluosilicic,	? 96.86	Calcium,	90
gallic,	? 63	chloride,	85
hydriodic, (iod. 124+hyd. 1)	125	iodide,	144
hydrobromic, (b. 75+hyd. 1)	76	protoxide, (lime)	22
hydrocyanic, (cyan. 26+hyd. 1)	27	phosphuret,	35.71
hydrofluoric,	19.86	sulphuret,	36
hyposulphurous, (s. 32+ox. 8)	40	Carbon,	6
hyposulphuric, (s. 32+ox. 40)	72	bisulphuret, (carb. 6+a. 32)	38
iodic, (iod. 124+ox. 40)	104	chloride,	42
malic,	? 70	perchloride, (carb. 12+chl. 108)	120
manganaceous,	? 83	oxide,	14
manganic,	? 60	phosphuret,	21.71
molybdic,	72	Cerium,	80
muriatic, (chl. 36+hyd. 1)	37	protoxide, (cer. 50+ox. 8)	58
nitric, dry, (nit. 14+ox. 40)	54	peroxide, (cer. 50+ox. 12)	62
nitric, liquid, (sp. gr. 1.5) (2w.)	73	Chlorine,	36
nitrous, (nit. 14+ox. 32)	46	hydrocarburet, (chl. 36+ol. gas 14)	80
osalic,	36	protoxide, (chl. 36+ox. 8)	44
c. 4w. (3w. Prout)	73	peroxide, (chl. 36+ox. 32)	68
perchloric, (chl. 36+ox. 56)	92	Chromium,	32
phosphorous, (p. 15.71+ox. 12)	37.71	protoxide,	40
phosphoric, (p. 15.71+ox. 20)	35.71	Cobalt, (39.5 Rothoff)	96
saccharatic,	? 104	chloride,	62
selenious, (sel. 40+ox. 16)	56	iodide,	180
selenic, (sel. 40+ox. 24)	64	protoxide, (cob. 26+ox. 8)	38
succinic,	80	peroxide, (cob. 26+ox. 12)	38
sulphuric, dry, (s. 16+ox. 24)	40	phosphuret,	41.71
sulphuric, liquid, (sp. gr. 1.8488,) (1w.)	49	sulphuret,	42
sulphurous, (s. 16+ox. 16)	32	Columbium,	? 185
tartaric,	66	Copper, (32 Thomson)	64
c. 1w.	75	chloride,	100
titanic,	48	bichloride,	136
tungstic,	120	iodide,	188
uric, (90 Prout)	72	protoxide,	72
Alcohol, (ol. gas 14+aq. vap. 9)	23	peroxide,	80
Alum, anhydrous,	262	phosphuret,	79.71
c. 25w.	487	sulphuret,	80
Alumina,	18	bisulphuret,	96
sulphate,	58	Cyanogen, (carb. 12+nit. 14)	26
Aluminium,	10	bisulphuret, (cyan. 26+a. 32)	88
Ammonia, (nit. 14+hyd. 3)	17	Ether, (ol. gas 28+aq. vap. 9)	37
Antimony,	44	Fluorine,	18.86
chloride, (ant. 44+chl. 36)	80	Glucinum,	18
iodide, (ant. 44+iod. 124)	168	Glucina,	26
protoxide, (ant. 44+ox. 8)	82	Gold,	200
deutoxide, (ant. 44+ox. 12)	86	chloride,	236
peroxide, (ant. 44+ox. 16)	60	bichloride,	272
sulphuret,	60	iodide,	272
Arsenic,	38	protoxide, (g. 200+ox. 8)	? 268
sulphuret, (realgar)	54	peroxide, (g. 200+ox. 24)	? 224
sesquisulphuret (orpiment)	62	sulphuret, (g. 200+a. 48)	? 248
persulphuret, (s. 32+a. 40)	78	Hydrogen,	1
Barium,	70	arsenuretted,	30
chloride,	106	carburetted, (carb. 6+hyd. 2)	8

* C means crystallized, w, water; and the numeral before w expresses the number of equivalents of water which the crystals contain.

† Proportional of arsenic, and $\frac{1}{4}$ of sulphur.

Hydrogen, bicarb. (ol. gas) (carb. 12+hyd. 2)	14	Potassium, sulphuret,	85
seleuiuretted,	41	Rhodium,	44
sulphuretted,	17	protoxide,	82
bisulphuretted,	33	peroxide,	98
Iodine,	194	Seelenium,	40
Iridium,	730	Silica,	16
Iron,	28	Silicium,	8
chloride, (ir. 28+chl. 36)	64	Silver,	119
perchloride, (ir. 28+chl. 54)	82	chloride,	146
iodide,	162	iodide,	234
protoxide, (ir. 28+ox. 8)	36	oxide,	118
peroxide, (ir. 28+ox. 12)	40	phosphuret,	124.71
sulphuret,	44	sulphuret,	126
bisulphuret,	60	Sodium,	24
Lead,	104	chloride,	58
chloride,	140	iodide,	148
protoxide, (1.104+ox. 8)	112	protoxide, (soda)	32
deutoxide, (1.104+ox. 12)	116	peroxide, (s. 24+ox. 12)	36
peroxide, (1.104+ox. 16)	120	phosphuret,	30.71
phosphuret,	110.71	sulphuret,	40
sulphuret,	120	Strontium,	44
Lithium,	10	chloride,	80
chloride,	46	iodide,	168
iodide,	134	protoxide, (strontia)	32
oxide, (lithia)	18	phosphuret,	50.71
sulphuret,	26	sulphuret,	60
Magnesium,	12	Sulphur,	16
chloride,	48	chloride,	32
oxide, (magnesia)	20	iodide,	140
sulphuret,	28	phosphuret,	31.71
Manganese,	28	Sulphuretted hydrogen,	17
chloride, (m. 28+chl. 36)	64	Tellurium, (Berzelius)	38
perchloride, (m. 28+chl. 144)	170	chloride,	40
protoxide, (m. 28+ox. 8)	36	oxide,	58
deutoxide, (m. 28+ox. 12)	40	Tin,	94
peroxide, (m. 28+ox. 16)	44	chloride,	120
sulphuret,	900	bichloride,	66
Mercury,	936	protoxide,	74
chloride, (calomel)	372	deutoxide,	73.71
bichloride, (corrosive sublimate)	334	phosphuret,	74
iodide,	448	sulphuret,	90
biniodide,	308	bisulphuret,	32
protoxide,	216	protoxide,	240
peroxide,	216	deutoxide (titanic acid)	48
sulphuret,	232	Tungsten,	96
bisulphuret,	48	deutoxide, (brown) (t. 96+ox. 16)	112
Molybdenum,	80	tritoxide, (tungstic acid) (t. 96+ox. 24)	120
protoxide, (m. 48+ox. 8)	64	Uranium,	216
deutoxide, (m. 48+ox. 16)	72	protoxide,	224
peroxide (molybdic acid) (m. 48+ox. 24)	28	deutoxide,	9
Nickel,	62	Water,	34
chloride,	150	Yttrium,	48
iodide,	34	oxide, (yttria)	34
protoxide, (n. 26+ox. 8)	38	Zinc,	70
peroxide, (n. 26+ox. 12)	41.71	chloride,	42
phosphuret,	42	oxide,	40.71
sulphuret,	14	phosphuret,	80
Nitrogen,	158	sulphuret,	72
bisulphuret, (cyanogen)	386	Zirconium,	72
chloride, (n. 14+chl. 144)	22	Zirconia,	73
iodide, (n. 14+iod. 372)	30	SALTS.	
protoxide, (n. 14+ox. 8)	8	Acetate of alumina,	68
deutoxide, (n. 14+ox. 16)	80	c. 1w.	77
Oxygen,	64	ammonia,	67
Palladium,	16.71	c. 7w.	130
oxide,	51.71	baryta,	138
Phosphorus,	87.71	c. 3w.	153
chloride,	87.71	cadmium, (c. 3w.)	133
bichloride,	21.71	copper, (acid 50+perox. 80)	130
carburet,	31.71	c. 6w. (com. verdigris)	184
sulphuret,	96	binacetate,	180
Platinum,	132	c. 3w. (distilled verdigris)	207
chloride,	168	subacetate,	210
bichloride,	104	lead,	162
protoxide,	112	c. 3w.	189
deutoxide,	112	lime,	78
sulphuret,	128	magnesia,	70
bisulphuret,	40	mercury, (c. 4w.)	90
Potassium,	76	potassa,	166
chloride,	164	silver,	111
iodide,	48	strontia, (c. 1w.)	92
protoxide, (potassa)	64	zinc,	155
peroxide, (p. 40+ox. 24)	55.71	c. 7w.	

Arsenate of lead,	170	Nitrate of strontia,	106
lime,	86	Oxalate of ammonia,	83
magnesia,	78	c. 3w.	71
potassa,	106	baryta,	114
binarsenate, (c. 2w.)	182	binoxalate,	180
soda,	90	cobalt,	70
binarsenate, (c. 4w.)	184	lime,	64
strontia,	110	nickel,	70
silver,	176	potassa,	84
Arsenite of lime,	78	c. 1w.	93
potassa,	98	binoxalate,	180
soda,	82	c. 3w.	138
silver,	168	quodroxalate,	198
Carbonate of ammonia,	39	c. 7w.	255
sesquicarb. (acid 83+am. 17+w. 9)	59	strontia,	88
bicarbonate, (1w.)	70	binoxalate,	184
baryta,	100	Phosphate of ammonia, (c. 3w.)	70.71
copper, (acid 22+perox. 80)	102	baryta,	113.71
iron, (acid 22+protox. 36)	88	lead,	147.71
lead,	134	lime,	63.71
lime,	80	magnesia,	55.71
magnesia,	42	soda,	67.71
manganese,	88	c. 12½w.	180.21
potassa,	70	Sulphate of alumina,	88
bicarbonate,	92	alumina and potassa,	262
c. 1w.	101	c. 25w. (alum)	487
soda,	84	ammonia, (c. 1w.)	66
c. 10w.	144	baryta,	118
bicarbonate, (c. 1w.)	85	copper, (acid 40+perox. 80)	190
strontia,	74	bipersulphate,	100
zinc,	64	c. 10w. (blue vitriol)	280
Chlorate of baryta,	144	iron,	76
lead,	188	c. 7w. (green vitriol)	139
mercury,	284	lead,	182
potassa,	124	lime,	68
Chromate of baryta,	130	c. 2w.	86
lead,	104	lithia, (c. 1w.)	67
mercury,	260	magnesia, (c. 7w.)	123
potassa,	100	mercury, (acid 40+perox. 216)	286
bichromate,	152	bipersulphate, (acid 80+perox. 216)	296
Muriate of ammonia,	84	potassa,	88
baryta, (c. 1w.)	124	bisulphate, (c. 2w.)	146
lime, (c. 6w.)	119	soda,	72
magnesia,	87	c. 10w.	162
strontia,	161	strontia,	92
Nitrate of ammonia,	71	zinc,	82
baryta,	132	c. 7w.	145
bismuth, (c. 3w.)	161	Tartrate of lead,	178
lead,	166	lime,	94
lime,	82	potassa,	114
magnesia,	74	bitartrate,	180
mercury, (acid 54+protox. 208+w. 18)	280	c. 2w. (cream of tartar)	198
potassa,	102	antimony and potassa, (c. 3w.) (tartar	
silver,	172	emetic)	363
soda,	86		

Adopted for this work from the third American edition of Turner's Chemistry, revised by Dr. Franklin Bache, and published by Mr. John Grigg, Philadelphia, by permission of both Editor and Publisher.

☐ The number for phosphorus having been altered from 12 (that given in Vol. I.) to 16.71, of course, the numbers of its compounds are changed. It is possible that other numbers may have been changed, but I have made no alterations in the above table; the numbers of some substances are still unsettled, and changes may not improbably be made in others.

TABLE of precipitants of the metals; also of their colors, when thrown down by ferro-prussiate of potassa, infusion of galls, hydro-sulphurets, and sulphuretted hydrogen. (This table should have followed page 33.)

NAMES.	PRECIPITANTS.	COLOR OF PRECIPITATES BY			
		<i>Ferro-prussiate of Potassa.</i>	<i>Infusion of Galls.</i>	<i>Hydro-sulphurets.</i>	<i>Sulph. Hydrogen.</i>
Platinum,	Muriate of ammonia,	0	0	Yellow,	Bl'k met. powder.
Gold,	Sulph. iron; Mur. tin; Nitr. mercury,	Yellowish white,	Green; met.	Yellow,	Yellow.
Silver,	Common salt,	White,	Yellow-brown,	Black,	Black.
Palladium,	Prussiate of mercury,	Deep orange,	0	Blackish brown,	Black brown.
Mercury,	Common salt; Heat,	White, passing to yellow,	Orange yellow,	Brownish black,	Black.
Copper,	Iron,	Red brown,	Brown,	Black,	Do.
Iron,	Succinate of soda, with per-oxide,	Blue, or white passing to blue,	Protox. 0; Perox. black,	Black,	Do.
Lead,	Sulphate of soda,	White,	White,	Black,	Do.
Tin,	Corrosive sublimate,	Do.	0	Protox. bl'k; Perox. yel'w	Brown.
Nickel,	Sulphate of potassa?	Do.	Grey-white,	Black,	0
Cadmium,	Zinc,	Do.	0	Orange yellow,	Orange Yellow.
Zinc,	Alkaline carbonates,	Do.	0	White,	Yellowish white.
Bismuth,	Water,	With dilute solutions, white,	Yellow,	Black brown,	Black brown.
Antimony,	Water; Zinc,	White,	White from water,	White,	Orange.
Manganese,	Tartrate of potassa,	Brown yellow,	0	Blackish,	Milkiness.
Cobalt,	Alkaline carbonates,	White,	Yellow-white,	Blackish,	0
Tellurium,	Water; Antimony,	White,	Yellow,	Yellow,	Yellow.
Arsenic,	Nitrate of lead,	Green,	Brown,	Green,	Brown.
Chromium,	Do.?	Brown,	Deep brown,	Chocolate,	.
Molybdenum,	Dilute acids,	Olive,	Orange red,	.	.
Tungsten,	Zinc, or galls,	.	Purple, pass. to deep blue,	.	.
Columbium,	Iron; Sulphite of ammonia,	Brown red,	Chocolate,	Brown yellow,	.
Selenium,	Mercury,	Grass green,	Red brown,	Grass green,	.
Osmium,	.	Milk-white,	.	.	.
Uranium,
Titanium,
Cerium,

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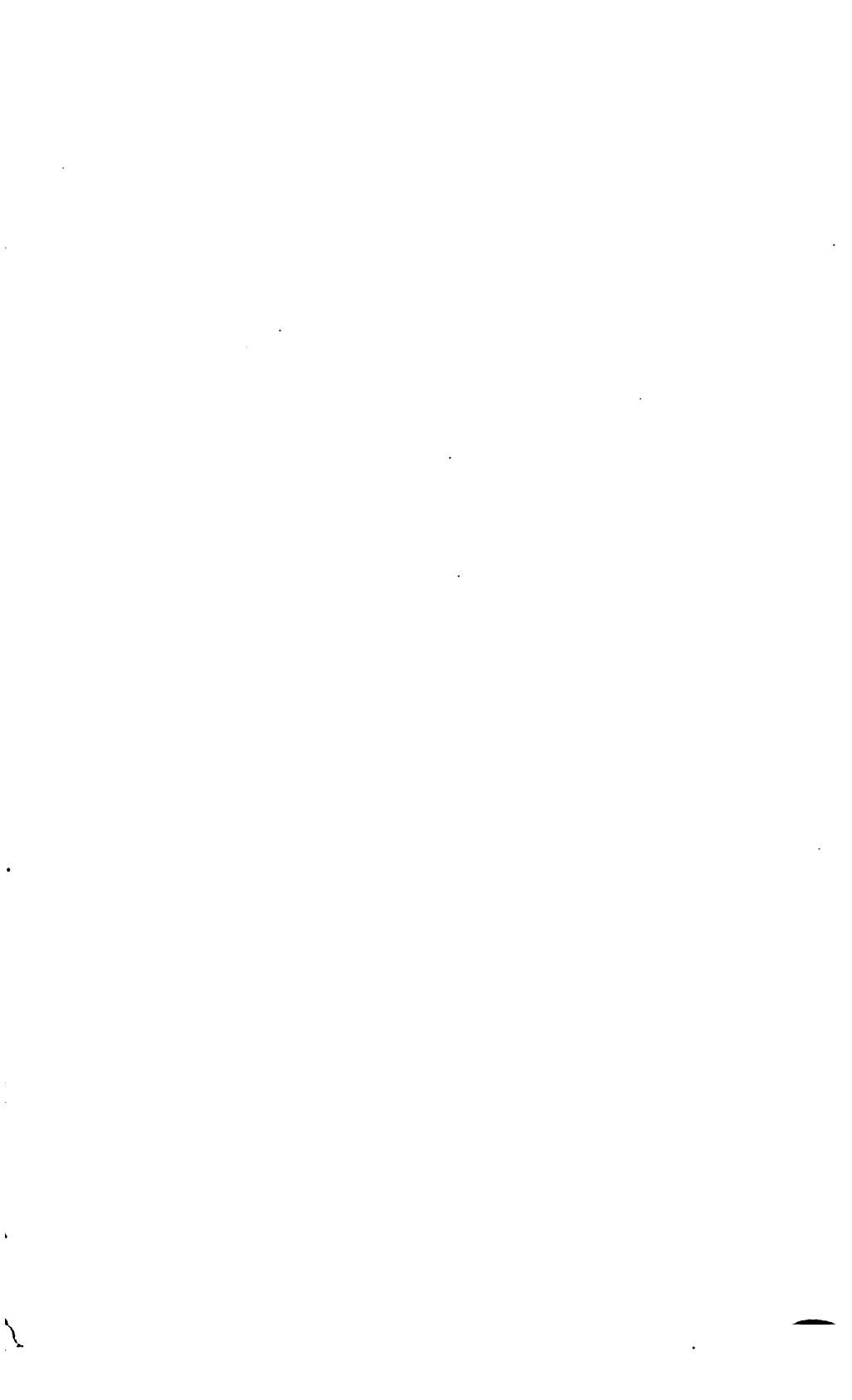
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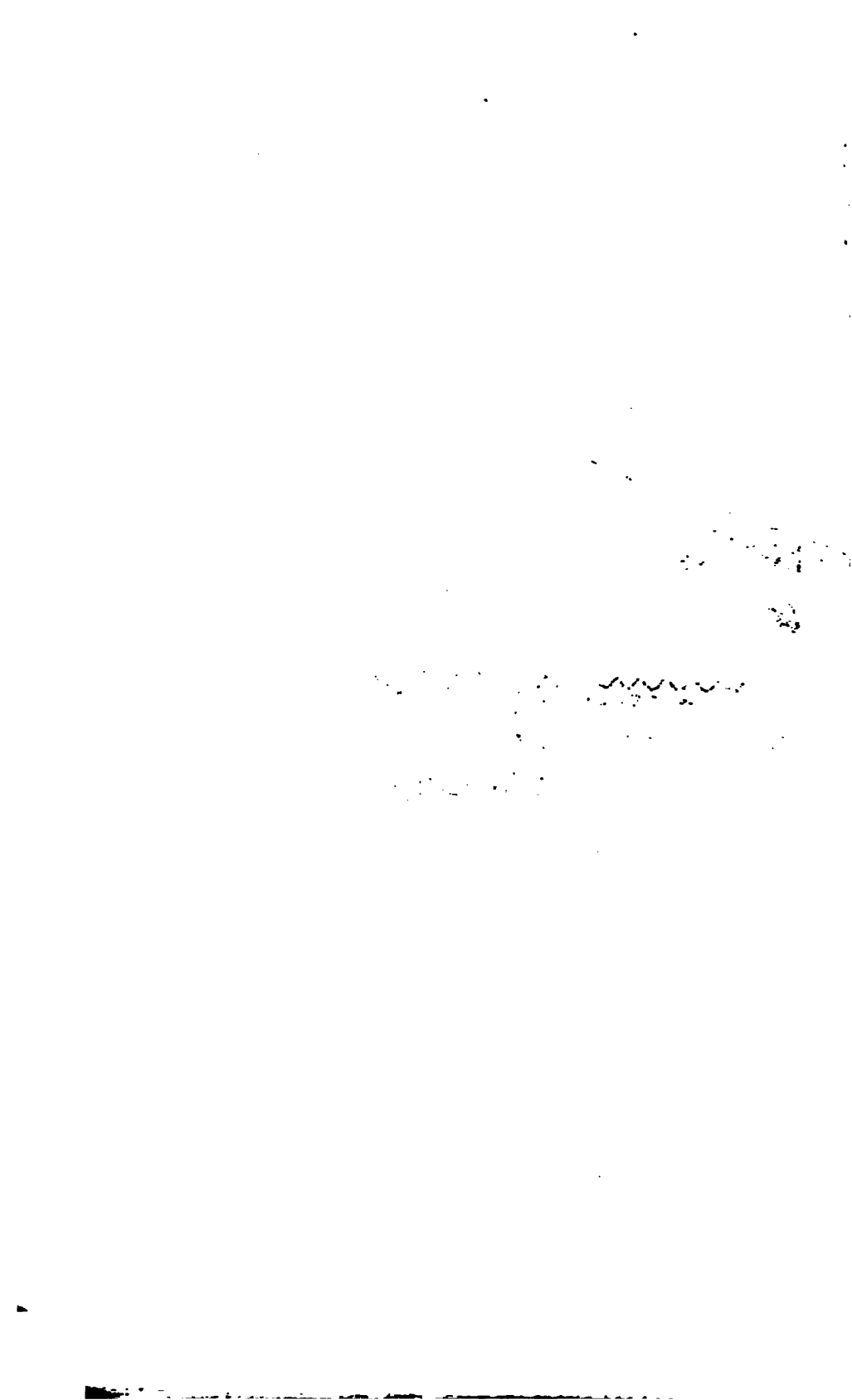
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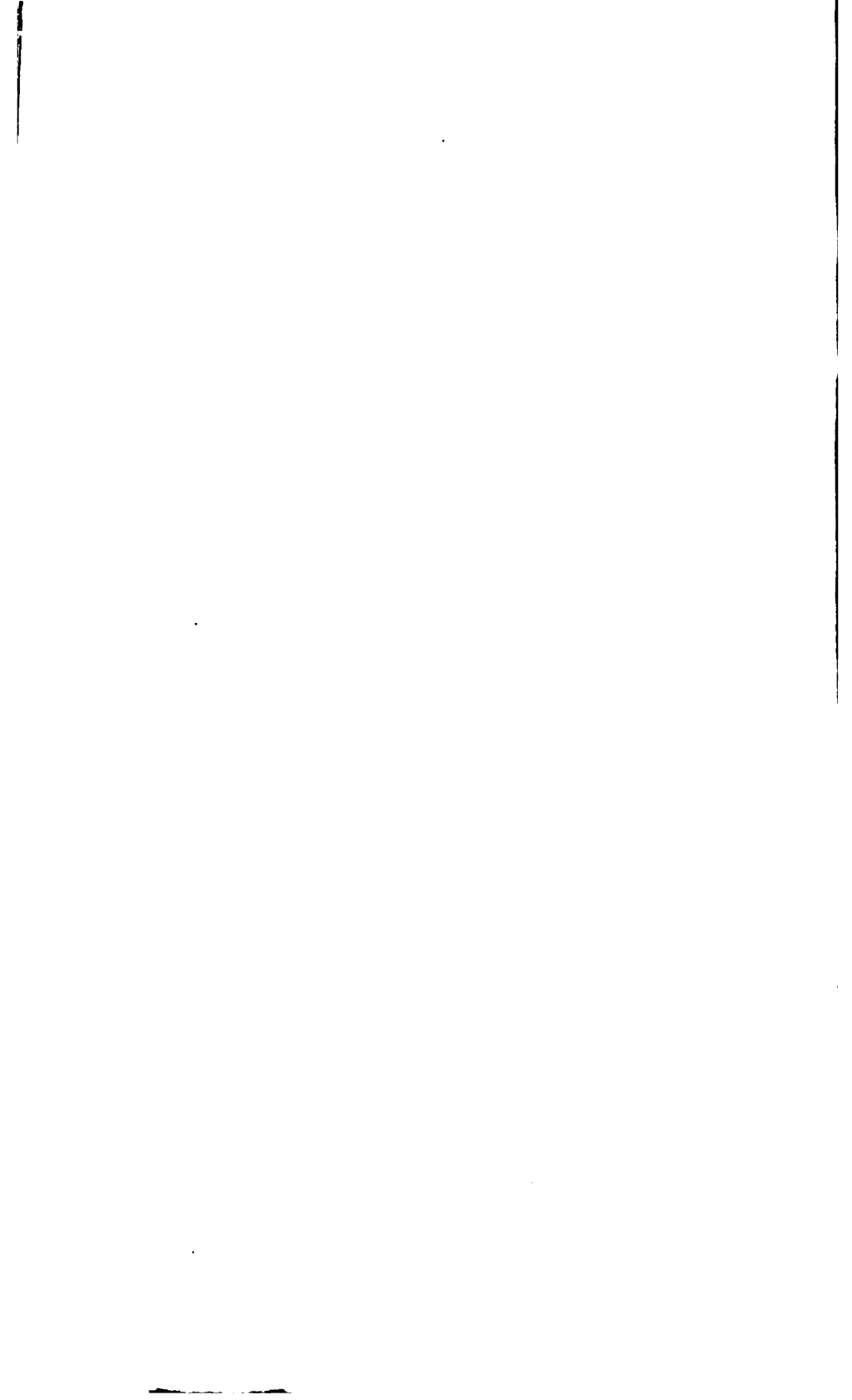
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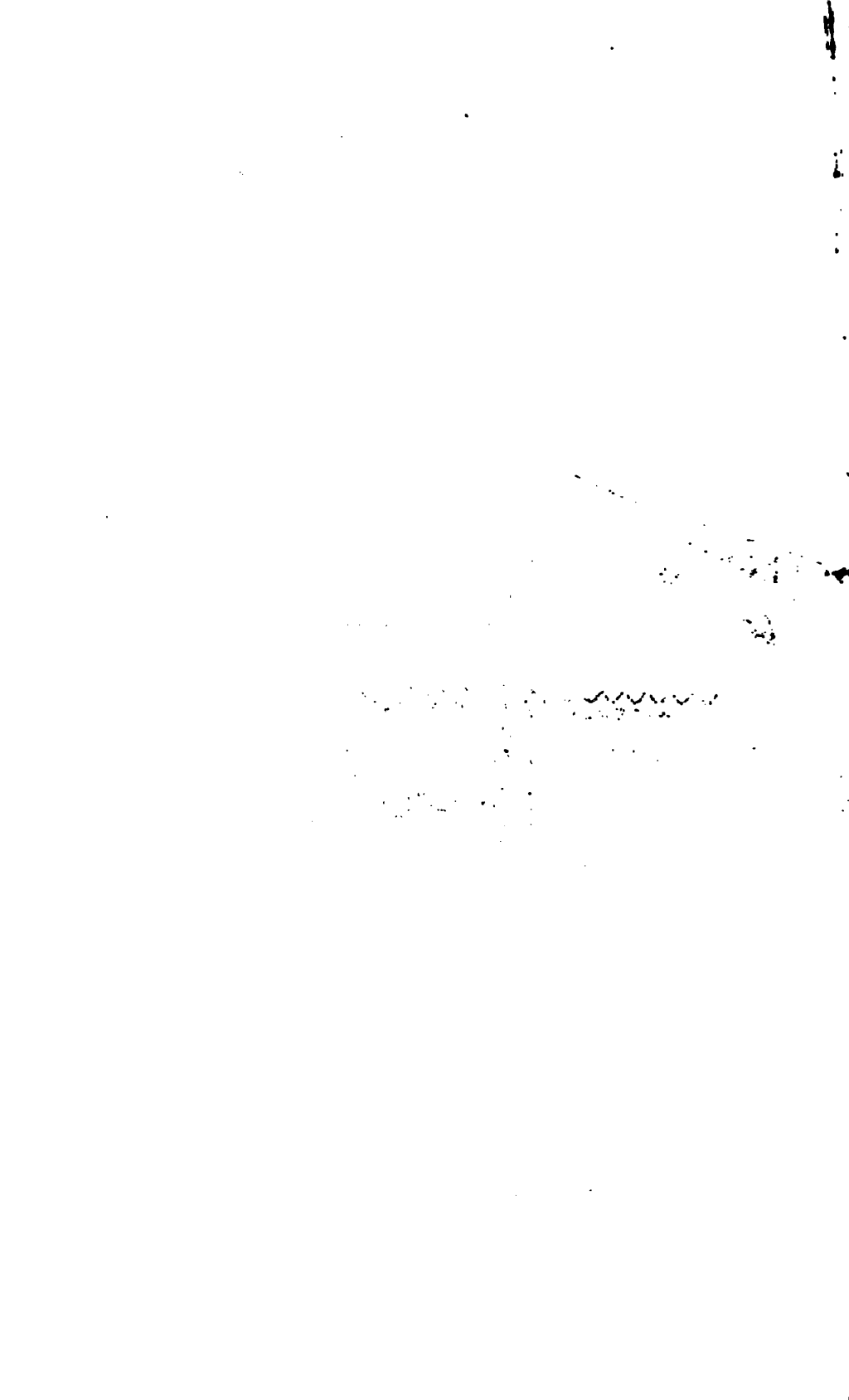
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